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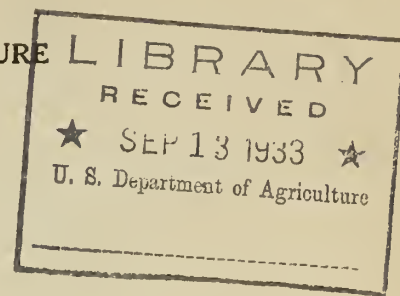
UNITED STATES DEPARTMENT OF AGRICULTURE
Bureau of Agricultural Economics

in cooperation with

Texas Agricultural Experiment Station

and with the assistance of

U. S. Bureau of Plant Industry
South Carolina Agricultural Experiment Station
Mississippi Agricultural Experiment Station, Delta Branch



STUDIES OF COLOR IN RAW COTTON

pt. 17

A Preliminary Report

Washington, D. C.
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Our thanks are here expressed to those who, by cooperation in supplying raw materials, have made this report possible. They include H. W. Barre, Director of the South Carolina Experiment Station at Clemson College, and B. C. Barre, who took care of the collection and shipment of the Super Seven cotton; W. E. Ayers, Director of the Delta Branch, Mississippi Agricultural Experiment Station at Stoneville from which Missdel No. 4 was supplied; S. H. Hastings of the Federal Bureau of Plant Industry who arranged for the cooperation with the United States Field Station at Bard, California from which the Acala and Pima cottons were supplied.

We also thank A. B. Connor, Director, and others at the Texas Agricultural Experiment Station who supplied material and who, through a cooperative agreement, are undertaking cooperative studies on the material supplied from the Temple, Lubbock, and Chillicothe sub-stations. The Texas report is to be issued at a later date.

STUDIES OF STABILITY OF COLOR IN RAW COTTON 1/

By Dorothy Nickerson, Color Technologist, and
Leona Dilworth Milstead, Junior Scientific Aid in Color,
Division of Cotton Marketing

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INTRODUCTION

As cottons come to the market they vary in factors of quality which are not altogether stable. This lack of stability in the elements of quality is a serious problem in standardization. Therefore, in connection with the work of cotton grade standardization a study of stability of some of the measurable factors of cotton quality was initiated during 1930 and 1931. The scope of this study was to be limited to a consideration of color and such other factors as might explain, or be associated directly or indirectly with, a study of color stability in cotton. The results of this work should provide information adequate for the solution of color-instability problems that arise in the work of cotton grade standardization.

During the season of 1930, cotton for this purpose was provided by the South Carolina Agricultural Experiment Station at Clemson College. In 1931 the work was expanded to include material from the following additional stations: the Delta Branch, Mississippi Agricultural Experiment Station at Stoneville; the United States Field Station at Bard, Calif.; and the Texas Agricultural Experiment Station through a cooperative agreement whereby the Texas station was to undertake cooperative studies on the material supplied from three Texas substations - Temple, Lubbock, and Chillicothe. The purpose was to determine the kind and amount of color changes in cotton and to study the extent to which changes in other factors of quality are related to these changes.

This report presents in preliminary form the results of this work to date.

1/ This project is a part of the program of the Cotton Utility and Standards Research Section which, as a part of the Division of Cotton Marketing, is in charge of R. W. Webb.

METHOD OF SETTING UP THE STUDY

No accurate information seemed to be available regarding stability of various factors and qualities of cotton. It is said on the one hand that creamy cottons bleach out; on the other hand, that they become yellow. Logically, both statements can not be true of the same cottons handled in the same way. Color, since it is an important grading factor, seemed to be a good starting point for a study of stability. It is easily measured and the cotton samples need not be destroyed in the process of measurement. The samples necessary for a study of color stability would also provide a series of cottons for measurements of color factors which it might be desirable to study in relation to color stability.

Therefore in 1930 a preliminary test was made with one variety of cotton at Clemson College, S. C. Its purpose was to discover the change in color that takes place in cotton left exposed in the field.

In the following season (1931-32) five varieties were studied. One of them was studied by means of samples that had been grown at three stations. The purpose this time was fivefold: To study the change in color of cotton lint caused by exposure in the field, as in the previous year; to study the change in color caused by late opening of bolls; to study the color of cotton opening at or after a heavy frost; to make comparisons between samples of a single variety grown under different conditions; and to make tests of changes in the foregoing samples when exposed to controlled conditions of humidity, light, heat, and other such environmental factors as might affect the color of the cotton.

To procure material for these studies, essentially the same procedure was followed each year. At the time bolls were opening profusely, several thousand of the newly opened bolls were tagged. Beginning on the date of tagging and continuing each following week as long as tagged bolls remained on the plants, 30 were picked and sent to Washington. This provided material for the study of the effect of field exposure on the color of cotton lint.

In order to study the effect of late opening of bolls, a separate block of cotton was picked clean of all open bolls at the time the first tagging was done. Each week thereafter all bolls that had opened in this separate block were picked, wrapped separately, and identified, and were sent to Washington at the time the tagged bolls were sent.

In addition, for studying the color of frost-opened bolls, the directions were that a thousand or more bolls partially opened, cracked, or ready to open, were to be tagged at the time of the first killing frost. At that time 30 bolls were to be sent to Washington; 30 more were to be picked and sent each following week until the supply of tagged bolls was exhausted.

Arrangements were made to have copies of weather data reports from each station sent to Washington.

In 1930 and 1931 the cotton received from South Carolina was Super Seven. From the Delta Branch Experiment Station at Stoneville the variety was Missdel #4. From the California-Arizona district the cottons were Pima and Acala. From the three Texas stations the cotton was a strain of Triumph, Ferguson 406. The choice of variety, except in the case of Super Seven, was made by the station cooperating, the selection in each case covering varieties available, or of particular interest, to that station. Considerable other work of a detailed nature ^{2/} has been done on Super Seven in our laboratories and since it is a strain (Strain 4) of a representative, purebred American cotton whose reputation for wilt resistance has been established, its use was requested for this study also. The Texas station reports that Ferguson Triumph #406 was selected because of its uniformity in type, having been line bred for a number of years, and its adaptation to conditions in the western part of the State where earliness of maturity is an important factor, especially at Lubbock.

COLOR MEASUREMENTS

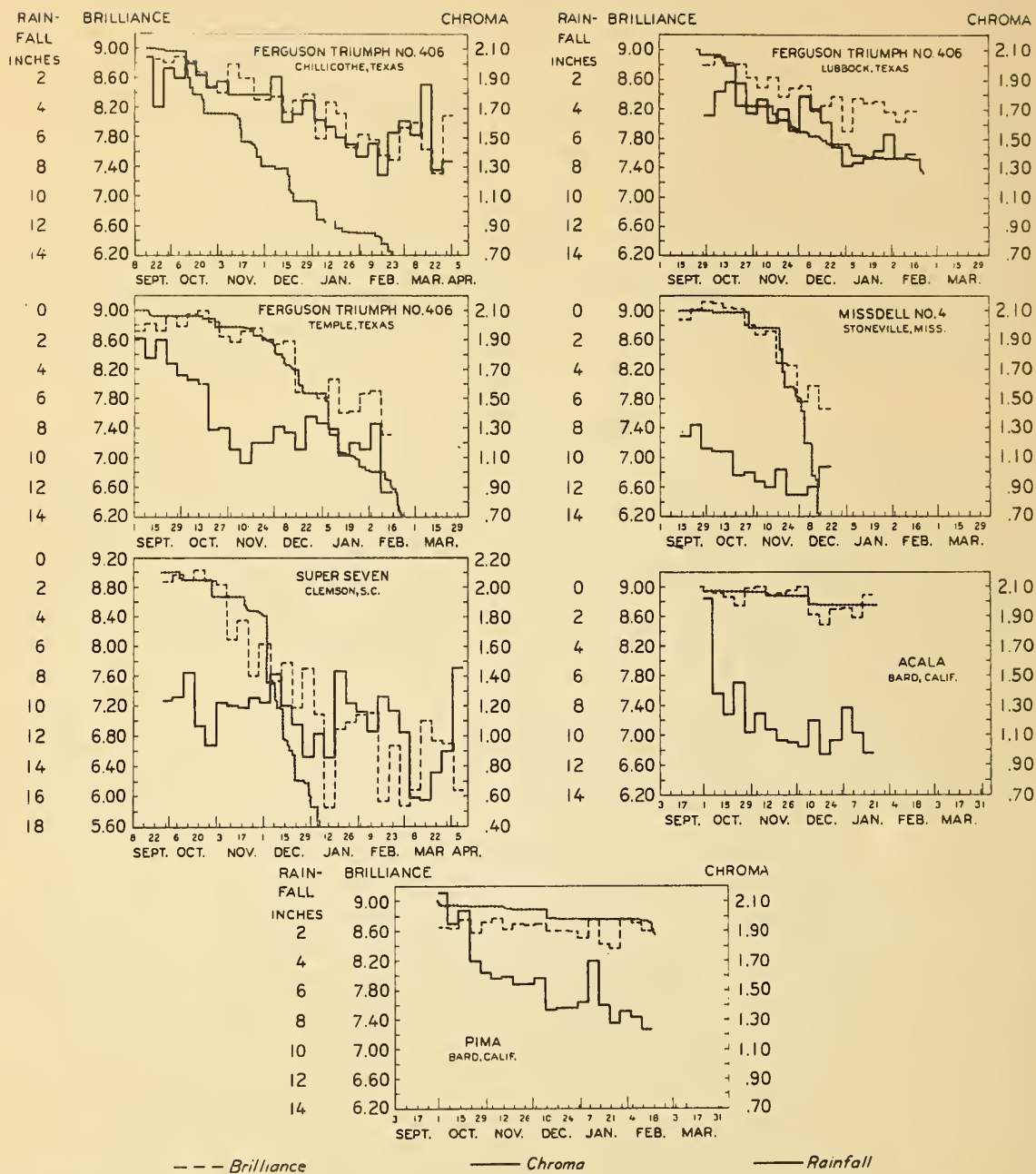
As the cotton was received in the Washington laboratory it was carefully sampled and the lint from 10 locks (about 50 seeds) was pulled off the seeds by hand. This cotton was more or less paralleled and was placed on cards to give an area somewhat over 4 inches in diameter, with the fibers packed thick enough so that no background color would show through. The samples are comparable with each other although they are not the same in preparation and leaf as they would be if they had been machine ginned.

The method used for measuring the color of the samples has been described elsewhere ^{3/ 4/}. Briefly, it consists of the comparison of the cotton color with that of a set of standard disks, the areas of which may be changed to allow the making of a color match. For cotton, the area measured is usually 4 inches in diameter, the match being made through a colorimeter at which an observer sits and matches the top and bottom halves of a circular observing field. By means of a spinning optical wedge the standard disk colors are mixed in the proportion in which they are exposed. The match is made by changing the disk areas until there is a color match between the halves of the observing field. The proportions of the disks exposed are then recorded and the figures are converted into terms of hue, brilliance, and chroma ^{3/}. The results of several correlations indicate that hue, or the color name - as red, yellow, green, blue, - may be eliminated from consideration in cotton work. The chief factors in grading cotton are brilliance, or brightness - the light-to-dark quality of colors; and chroma, or creaminess - the amount of yellow color apparent in the fiber. Each of these color qualities may be expressed in an arithmetic scale; brilliance from 0 (black) to 10 (white), and chroma from 0 (neutrality or gray) to 10, 12, or 14 (whatever may indicate the ultimate strength of a color, 10 being the chroma of a vermillion red pigment).

2/ Farr, Wanda K. - Cotton Fibers. I. Origin and Early Stages of Elongation. Contributions from Boyce Thompson Inst., vol. 3, No. 3, pp 441-458, 1931.

3/ Nickerson, Dorothy - A Method for Determining the Color of Agricultural Products. Tech. Bull. 154, U.S.D.A., 1929.

4/ Nickerson, Dorothy - Application of Color Measurement in the Grading of Agricultural Products. Mimeographed Report, U.S.D.A., 1932. (See page 28 for discussion regarding tolerances in terms of brilliance and chroma for "seeing the color of cotton.")



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FIGURE 1 - COLOR CHANGE IN COTTONS ACCORDING TO THE LENGTH OF TIME EXPOSED IN THE FIELD. RAINFALL IS ALSO INDICATED.

A DISCUSSION OF THIS CHART IS FOUND IN THE TEXT. THE CHIEF POINTS ARE: (1) THE UPLAND COTTONS TESTED AT TIME OF OPENING ARE FAIRLY CONSTANT IN BRIGHTNESS; (2) UPLAND COTTONS AT TIME OF OPENING VARY GREATLY IN AMOUNT OF CREAMINESS OR CHROMA; (3) THE CREAMIER COTTONS SEEM TO HOLD THEIR BRIGHTNESS BETTER THAN THE WHITER COTTONS; (4) IN MOST CASES THERE SEEMS A HIGH CORRELATION OF AMOUNT OF RAINFALL WITH CHANGE IN BRIGHTNESS.

Measurements of Samples Exposed in the Field

To show the trend of color change, Figure 1 is presented. On each graph included in this figure the brilliance change, the chroma change, and the cumulative rainfall (on an inverted scale) are plotted against the time that the cotton was exposed in the field.

The brilliance, or brightness, of the upland cottons is about the same to start with. Pima, not an upland cotton, is somewhat darker. In a general way it may be observed that the brilliance change seems to bear some relation to the amount of rainfall, a closer relationship being found in cottons that lose, or do not have much chroma or creaminess.

Against this factor of constant brightness at time of opening, the amount of creaminess varies with the cotton under consideration. The three cottons from Texas are the same variety, yet Chillicothe - or west Texas - has more creaminess at the beginning of the season and loses its color more slowly than do either of the other two cottons of the same variety, even though it had more rainfall. The color in the cotton from Lubbock changed very little; it did not have as much creaminess at the first of the season as did Chillicothe. It retained a higher brightness at the end of the season, and that, together with the retention of considerable of its yellow color, gave a result at the end of the season better than was shown in several of the other cottons examined. (On these charts which show the relative amounts of brilliance and chroma, it is not possible to indicate grade, but in later figures these color changes will be translated into relative terms of grade.) The Temple cotton had considerable creamy color for the first few weeks after opening, but beginning with the sample received the fourth week after opening, the chroma - or amount of yellow color - dropped very quickly to a low and more-or-less constant level.

Against these three cottons that started out with considerable creaminess, a cotton from the Delta district at Stoneville may be compared. The brightness, as with all the other upland cottons considered, is high at the beginning of the season. But the cotton has very little creaminess. It therefore looks "whiter" than the creamy cottons with which it is compared. And even the small amount of creaminess that it does have is not retained if the cotton is exposed in the field. It is soon reduced, as may be seen from the downward trend of the line indicating chroma.

Another cotton, taken from the East, grown at Clemson College, S. C., shows a similar "whiteness", or lack of yellow color, at the beginning of the season. This cotton seems to show considerably more irregularity of change than the other cottons, but, in part at least, this is owing to the yellow color of the Clemson soil which clings to some of the cotton. The chief color difference between these two cottons is not in chroma but in the rate with which brightness is lost. The Stoneville cotton loses brightness, week by week, the change being slow and fairly regular: the Clemson cotton loses its brightness more rapidly. This rapid change is not merely a chance happening of samples during one season. A comparison of 1930 with 1931 samples from Clemson indicates that such a change took place during both years.

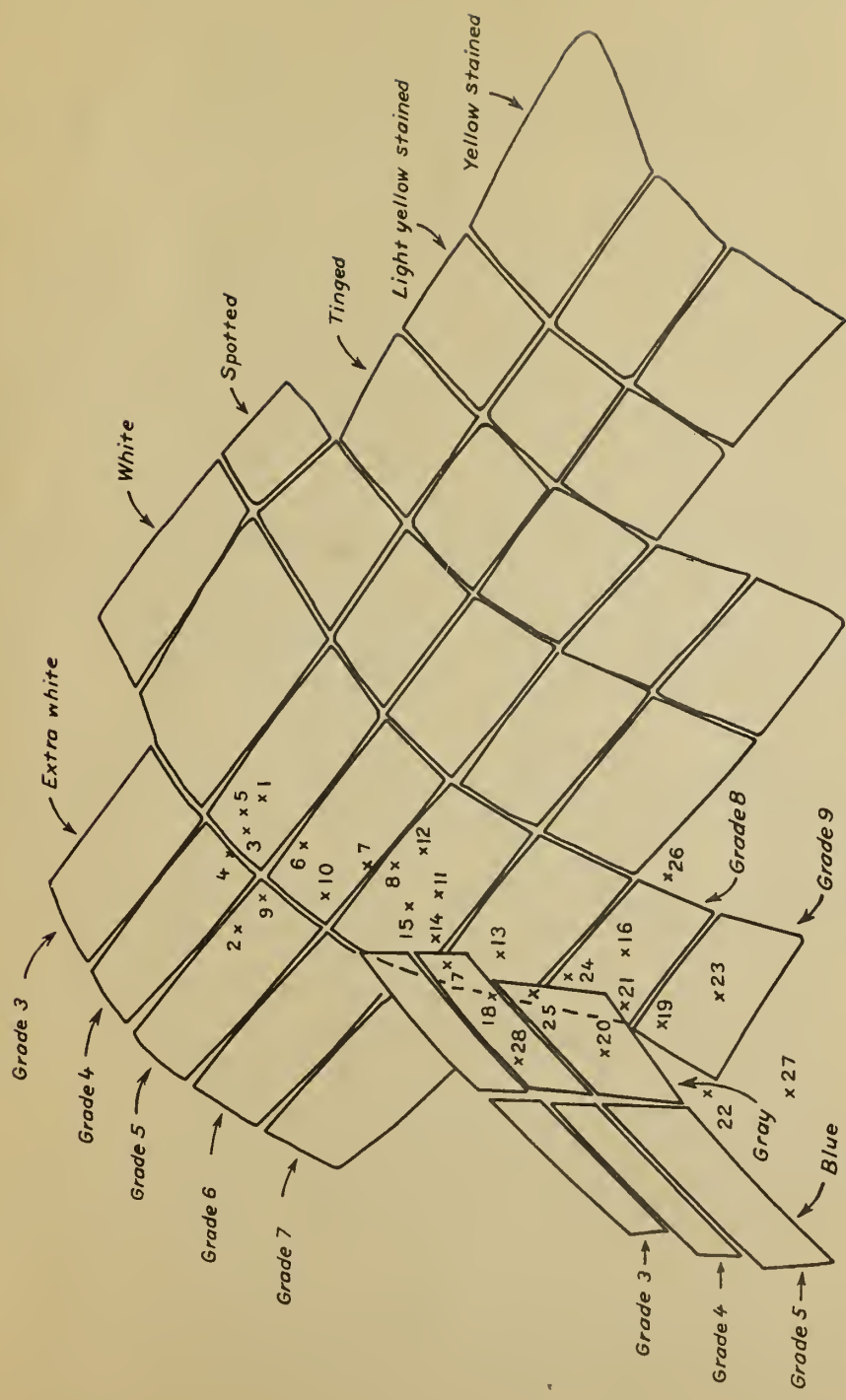
Against these cottons already measured and recorded, it seems desirable to compare cottons grown under irrigation. In that way something may be seen of the part that rainfall and excessive sunshine play in changing the color of cotton. An Acala cotton, grown in the California-Arizona district, shows little brightness change over a period of several weeks; chroma, however, dropped very rapidly. For comparison, a Pima cotton grown at the same place was included in the study. The brightness of the Pima was never so great as that of the other cottons, but under irrigated conditions it upholds its brightness very well. Its chroma, a characteristic yellow color, was high during the first few weeks of the season, but soon dropped to give a color much "whiter" than that thought of as the characteristic color of American-Egyptian cottons.

The change depicted on each of these seven graphs in Figure 1 is a change measured in a different sample picked on successive weeks from the same field of cotton, the cotton having been tagged when the bolls were first opened in order to insure that the time of exposure would be measured from a constant base.

All of these samples were picked by hand and the fibers were separated from the seed by hand. They therefore lack the normal leaf content for the various grades. They lack also the ginning preparation which aids a classer in identifying the grade of any cotton sample. However, despite difficulties, the samples were graded, and since these grades are in general agreement with the grade that would be given as a result of conversion of laboratory measurement, the grades are shown, on a basis of color measurements, in Figures 2 and 3.

Figure 2, which reminds one of a small airplane, is in reality a miniature color chart. On it the general relationship of the grades is plotted. The figure was drawn up by plotting the average color measurements in terms of brilliance and chroma for each of the official standards for grade and color of cotton, on a chart, and then drawing the best connecting line through each class and grade of cotton. For example, smooth curves drawn through the brilliance and chroma measurements for the Extra White, for the Tinged, and for the Stained grades were found to be approximately parallel, while lines drawn to be as close to as many as possible of the brilliance and chroma measurements of the Good Middlings, Strict Middlings, etc. provided a series of straight lines parallel to each other. The second set of lines crossed the first set, as indicated on charts, and thus provided a basis for the chart. The curved effect on the chart is necessary in order to indicate the real color relationship of the grades. The high grades are brighter and creamier (or yellower) than the lower grades of the same class. The average for each of the White grades falls within the block assigned to it; it is not always in the center. Figure 3 eliminates all but the White grades in order that the samples that do not fall within these grades may be shown in their relation to the White grades. The scale in Figure 3 is smaller than that in Figure 2 but is in the same proportion.

The color of individual samples of Ferguson Triumph #406 received week by week from Chillicothe, Texas, is shown in Figure 2. The numbers indicate the number of weeks each sample was exposed. The general results indicate that samples picked during the first few weeks have the color of Strict Midd-

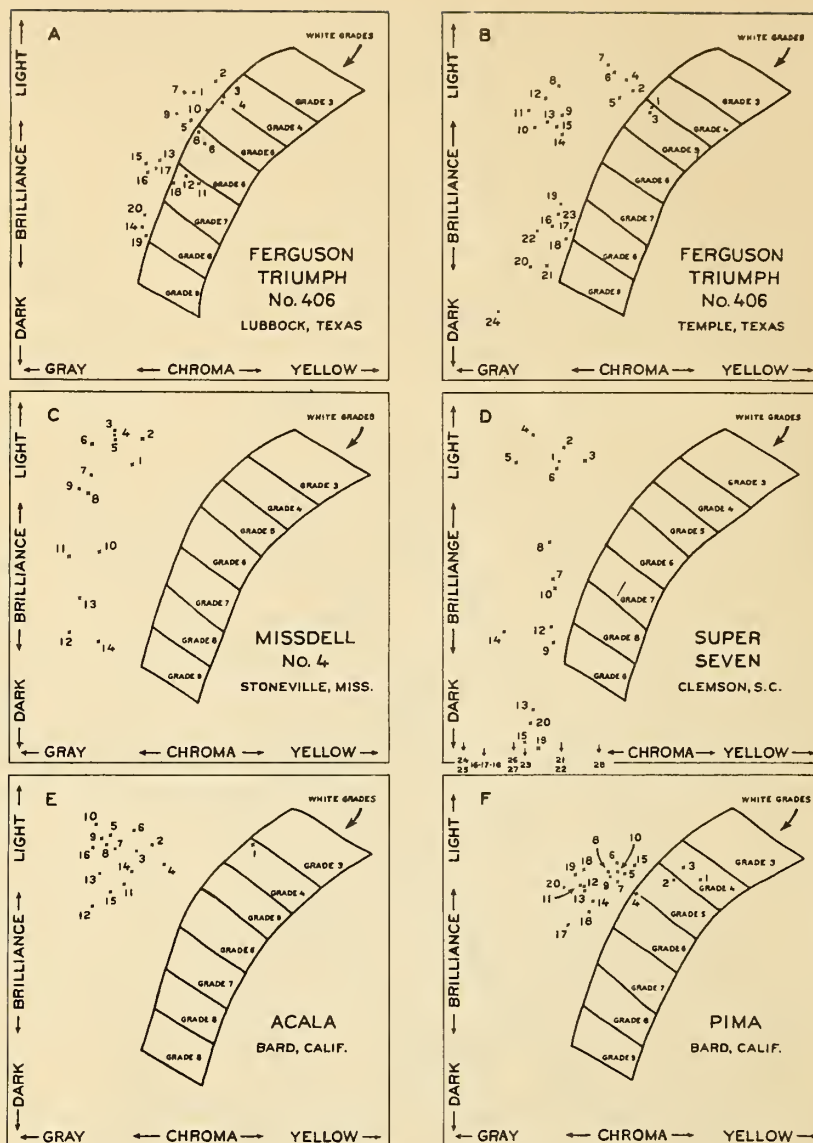


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FIGURE 2 - COLOR CHANGE OF SAMPLES IN RELATION TO GRADE.

ON THIS CHART THE GENERAL RELATIONSHIP OF THE GRADES OF COTTON ARE GIVEN. (SEE TEXT FOR EXPLANATION.) THE NUMBERS ACCOMPANYING THE CROSSES INDICATE THE NUMBER OF WEEKS OF EXPOSURE BEFORE PICKING. THE LATE PICKED SAMPLES ARE LOWER IN GRADE THAN EARLY PICKED SAMPLES. MOST OF THESE SAMPLES SEEM TO FALL WITHIN THE GENERAL RANGE OF THE WHITE STANDARDS.



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FIGURE 3 - COLOR CHANGE OF SAMPLES IN RELATION TO GRADE.

ON EACH OF THESE 6 GRAPHS THE COLOR IS SHOWN IN THE SAME RELATION AS ON FIGURE 2. THE GENERAL POSITION OF SEVEN WHITE GRADES, GOOD MIDDLING TO GOOD ORDINARY, IS SHOWN IN ORDER THAT THE COLOR RELATIONSHIP OF THE INDIVIDUAL SAMPLES TO THESE WHITE GRADES MAY BE APPARENT. THE FIGURES ACCOMPANYING THE CROSSES INDICATE THE NUMBER OF WEEKS EXPOSURE BEFORE PICKING. THERE IS A DECIDED VARIATION IN GRADE FROM HIGH TO LOW IN ALL OF THE GROUPS, BUT THE ACALA AND PIMA COTTONS NEVER BECAME AS DARK AS OTHER COTTONS, UNDOUBTEDLY BECAUSE OF LACK OF RAINFALL. PIMA COTTON, NOT AN UPLAND VARIETY, IS GRADED ON STANDARDS FOR AMERICAN EGYPTIAN COTTON, BUT THE PIMA SAMPLES RECEIVED FOR THIS TEST ARE SHOWN HERE SO THAT THEY CAN BE COMPARED FOR COLOR WITH THE OTHER COTTONS. PIMA IS CREAMIER AND DARKER WHEN IT FIRST OPENS (THAN THE UPLAND COTTONS) BUT, IN THE TEST, ON EXPOSURE IT LOSES MUCH OF ITS CREAMINESS. THERE IS A DIFFERENCE BETWEEN THESE SEVERAL SERIES OF COTTONS IN AMOUNT OF YELLOW COLOR NATURAL TO EACH. WHILE SOME SAMPLES ALMOST COINCIDE WITH THE WHITE STANDARDS, OTHERS ARE DISTINCTLY ON THE "WHITE" SIDE, THAT IS, TO THE LEFT.

ling White cotton. As the weeks go by the color changes until the cottons finally are "below grade". For the most part these Chillicothe samples fall within the range of the White grades.

In Figure 3 A the Lubbock, Texas, samples of the same variety are shown. Not as many samples were received from Lubbock as from Chillicothe but the trend is about the same except that the cottons are in general a bit on the white or gray side of the White standards, some of them actually getting over into Extra White and Gray grades.

The Temple, Texas, samples (still the same variety) in Figure 3 B, are still whiter; none except the very first samples having color within the range of the White boxes.

The grouping of the samples in this last chart may or may not be significant, but it is worth noting, since the same, but less definite, grouping can be detected in several of the other charts. In this paper there is no intention of discussing possible causes for the changes indicated, but it is suggested that it would not be improbable to find physiological causes for these jumps that appear to take place as the color of the cotton changes. There seem to be three distinct groups of color.

In Figure 3 C the cottons shown are considerably whiter than the White grades. These are samples of Missdel #4 from the Delta district at Stoneville, Miss. The brightness of the first several samples is very high - higher than the average of the Good Middling White box. (A horizontal line drawn anywhere on the chart indicates cottons of equal brightness; if a sample is toward the right of the chart on such a line it is of equal brightness but of greater chroma or creaminess than a sample further toward the left of the chart.)

Samples of Super Seven from Clemson College, S. C. are plotted in Figure 3 D. These, like the Delta samples, are whiter than the White standards. They are, on the whole, not quite so bright, even for the first few samples, as the Delta samples, although they are equal in brightness to the Strict Middling and Good Middling White grades. The last several samples are far below-grade in color, which would indicate that it is particularly important that this cotton be picked within the first month or so after opening. The late-picked samples have a peculiar dark-gray streak in them, the cause of which has not yet been identified. Such a streak has appeared in the late-picked samples for both 1930 and 1931.

The Acala cottons from Bard, Calif. plotted in Figure 3 E, are, with the exception of the first sample, whiter than the White grades. The brightness of the first few samples does not seem so great as the brightness of the Delta cottons. Nor, on the whole, are the samples as white as the Delta cottons measured.

The Pima cotton from Bard, Calif. is plotted in Figure 3 F in its color relation to the Upland cottons. Pima cottons are graded according to standards for American-Egyptian cotton, therefore the grades indicated in the figure should not be applied to this cotton. However, it may be seen that this cotton loses its outstanding color - which is creamier and darker than that of the

upland cottons - after it has been open in the field for only a few weeks. The brightness remains fairly constant for some time, but there is a loss of chroma. Note again the rather distinct separation of these samples into three groups.

The seven graphs included in Figures 2 and 3 indicate the relation to standard grades of the color changes that take place owing to exposure in the field. As pointed out previously, the grades assigned to these samples, because of lack of normal leaf content and ginning preparation, are not the same as they would be if these cottons had been handled commercially. But, since the changes indicated here are entirely due to color rather than to trash, the grades assigned err on the conservative rather than on the liberal side. If the samples had normal leaf content, the grade would be even lower.

Measurements of Cottons Maturing Week by Week During the Season

The second portion of the study had to do with bolls opening week by week. The purpose was to see what difference might exist between cottons opening early and opening late in the season. Only a few places had much cotton that continued to open week after week. The information is hardly enough on which to base conclusions, but it is presented in Figure 4. It is hoped that more information regarding this part of the study may become available during the 1932 season.

Measurements of Cottons Opening by or After Frost

The third portion of the study had to do with bolls opening by or after a killing frost. In 1931 only those samples indicated in Figure 5 were received. From this figure it is evident that the samples from Chillicothe which opened at or after frost are very yellow. (High chroma for these cottons means a high amount of yellow.) The samples of Acala cotton are also rather yellow. They become yellower for a period of a month (Nov. 28 to Dec. 26), then begin to lose chroma. The Pima cotton does not seem to be yellower when opened by frost than when opened normally at the first of the season.

COLOR OF WEATHERED RAW COTTON AS AN INDEX OF OTHER ELEMENTS OF QUALITY

The purpose of this study was to determine the kind and amount of color change that takes place in cotton exposed to varying conditions and to study the extent to which changes in other factors might be related to or associated with these changes. It is possible, to use one example, that those factors which have a detrimental effect upon the color of raw cotton during exposure in the field may also have a detrimental effect on other elements of quality. If this should be the case, color might prove a rough index of such other quality elements; it would not be the cause but might be used as a secondary indication. In order to discover whether such relations exist, the strength, length, and moisture regain were examined in relation to the length of time the samples were exposed. The information given in the several following figures may be taken to indicate only rough trends since the study was set up primarily for the determination of the color change rather than to test these other possibilities. As the material offered a convenient opportunity to procure some information in this direction, a limited amount of work has been done.

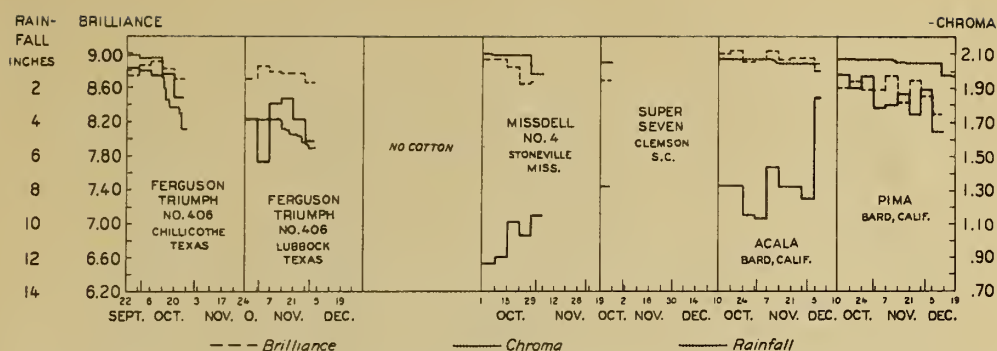
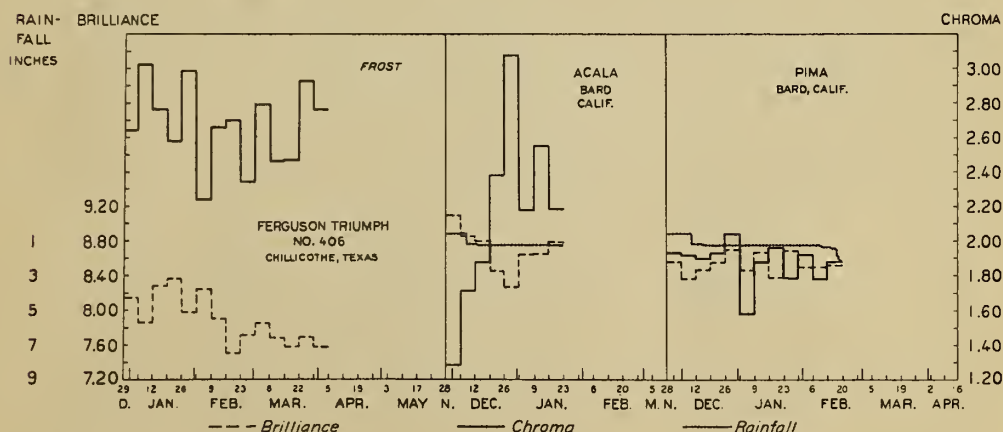


FIGURE 4 - COLOR OF COTTONS OPENING WEEK BY WEEK UNTIL LATE IN THE SEASON.

BRIGHTNESS OF THE COTTONS (BRILLIANCE ----) SEEMS ON APPROXIMATELY THE SAME LEVEL IN THE FIRST PICKINGS. LUBBOCK, STONEVILLE, ACALA, AND PIMA SAMPLES SEEM TO GET DARKER AS THE SEASON ADVANCES. THESE COTTONS DO NOT HAVE A DEFINITE TREND AS THEY HAVE IN FIGURE 1. CONSIDERABLE VARIATION IN CREAMINESS OF COTTONS IS INDICATED, BUT NO DEFINITE TREND IS APPARENT, ALTHOUGH CHILLICOTHE SEEMS TO LOSE CREAMINESS, AS DOES LUBBOCK; STONEVILLE SEEMS TO GAIN CREAMINESS THE LATER IT OPENS. THE LAST ACALA SAMPLE IS VERY CREAMY, BUT THE FACT THAT THIS PARTICULAR SAMPLE OPENED AFTER FROST PROBABLY ACCOUNTS FOR THIS SUDDEN CHANGE. PIMA SEEMS TO LOSE CREAMINESS. THUS THERE IS NO TREND IN A SINGLE DIRECTION.



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FIGURE 5 - COLOR OF COTTONS OPENED AT FROST TIME AND ALLOWED TO REMAIN IN THE FIELD WEEK AFTER WEEK.

THE AMOUNT OF YELLOW TINGE OR STAIN IN THE CHILLICOTHE SAMPLES IS HIGH, AS SHOWN BY THE SOLID LINE. THERE IS VARIATION WEEK BY WEEK, OWING TO THE FACT THAT WHILE SOME LOCKS ARE VERY YELLOW, OTHERS ARE WHITE, AND THE PROPORTION OF YELLOW AND WHITE BOLLS IS NOT THE SAME EACH WEEK. THE TREND IN BRIGHTNESS, AS THESE COTTONS REMAIN IN THE FIELD, IS DOWNWARD; THAT IS, THEY BECOME DARKER THE LONGER THEY ARE EXPOSED. THE ACALA SAMPLES SEEM TO GET YELLOWER AND YELLOWER FOR SEVERAL WEEKS, AND THEN THE TREND IS TOWARD REDUCTION OF YELLOWNESS. THE PIMA COTTON DOES NOT SEEM TO BE YELLOWER WHEN OPENED BY FROST THAN WHEN OPENED NORMALLY AT THE FIRST OF THE SEASON.

Strength and Length Tests

In Figure 6 the results of a series of strength tests are shown. The strength measurements 5/ were made on 10 bundles of fibers from each lot of cotton. Each bundle was made of fibers from a single seed. Thus only fibers from 10 seeds, picked at random, are included for each lot. The method of strength measurement is a long, tedious process, and while the results show numbers of ups and downs (which are undoubtedly the result of the sampling method) they do not show enough of a definite trend to warrant the measurement of many more samples for this study. The results are expressed in terms of 1,000 pounds per square inch. If there is a trend, it is one of reduced strength as the cotton remains exposed in the field for longer and longer periods of time.

The length measurements 6/ were calculated from two fiber arrays 7/ of each cotton included in the length study. Ten seeds were selected at random from the 30-boll samples sent to the laboratory from the field. Reading from the longest fibers, the length at the 25 per cent point by weight in the array, has been adopted; that is, 25 per cent of the fibers by weight are equal to or longer than the selected basis. An examination of the length information shown in Figure 6 will indicate no definite trend regarding a change of length with time of exposure.

A comparison of the length and strength data brings out the fact that the longer cottons of these series are definitely stronger than the shorter cottons. This is in line with general observations after a study of many cottons in one cotton-testing laboratory. It also brings out the fact that the cottons opening after frost are, in ^{all} cases, longer than other samples of the same variety, and stronger than other samples picked late in the season from the same field. This may best be seen by reference to Figure 6 in which the frost cottons are shown in relation to the regular series exposed in the field.

No length or strength measurements have yet been made on the series of samples opening week by week late into the season. However, in regard to similar material, reference may be made to the work of Armstrong and Bennett 8/ at the South Carolina Experiment Station at Clemson College. In a report not yet published on length measurements made by the same general method on the same Clemson cotton they state that in one of their experi-

5/ Chandler, E. E. - A New Method for Determining the Strength of Cotton. Mimeographed Report. U.S.D.A. 1926. (Details of method subsequently revised, not yet published.)

6/ Webb, R. W. - The Suter-Webb Cotton Fiber Duplex Sorter and the Resulting Method of Length-Variability Measurements. Proceedings of American Society for Testing Materials, Phila. vol. 32, part II, 1932.

7/ These arrays were made by W. W. Copithorn with the cooperation of F. L. Gerdes, in charge of the cotton ginning investigations of this Bureau at Stoneville, Miss. Mr. Gerdes also cooperated in conducting moisture tests for this study.

8/ Armstrong, G. M. and C. C. Bennett. - Some Factors Influencing the Variability in Length of Cotton Fibers on Individual Plants as Shown by the Sorter Method. Unpublished manuscript, cited by permission of the authors. 1932.

ments the bolls produced from late blooms had shorter lint than bolls which flowered a week earlier and that there was a greater percentage of short fibers in bolls which, although they bloomed on the same date, opened at a later date (58 days against 75.1 days). They also found that the "position of the boll along the vertical axis or the horizontal axis does not seem to be of very great importance in determining the length of lint, though there is a distinct tendency for shorter lint to be produced near the top of the plant when grown in the field."

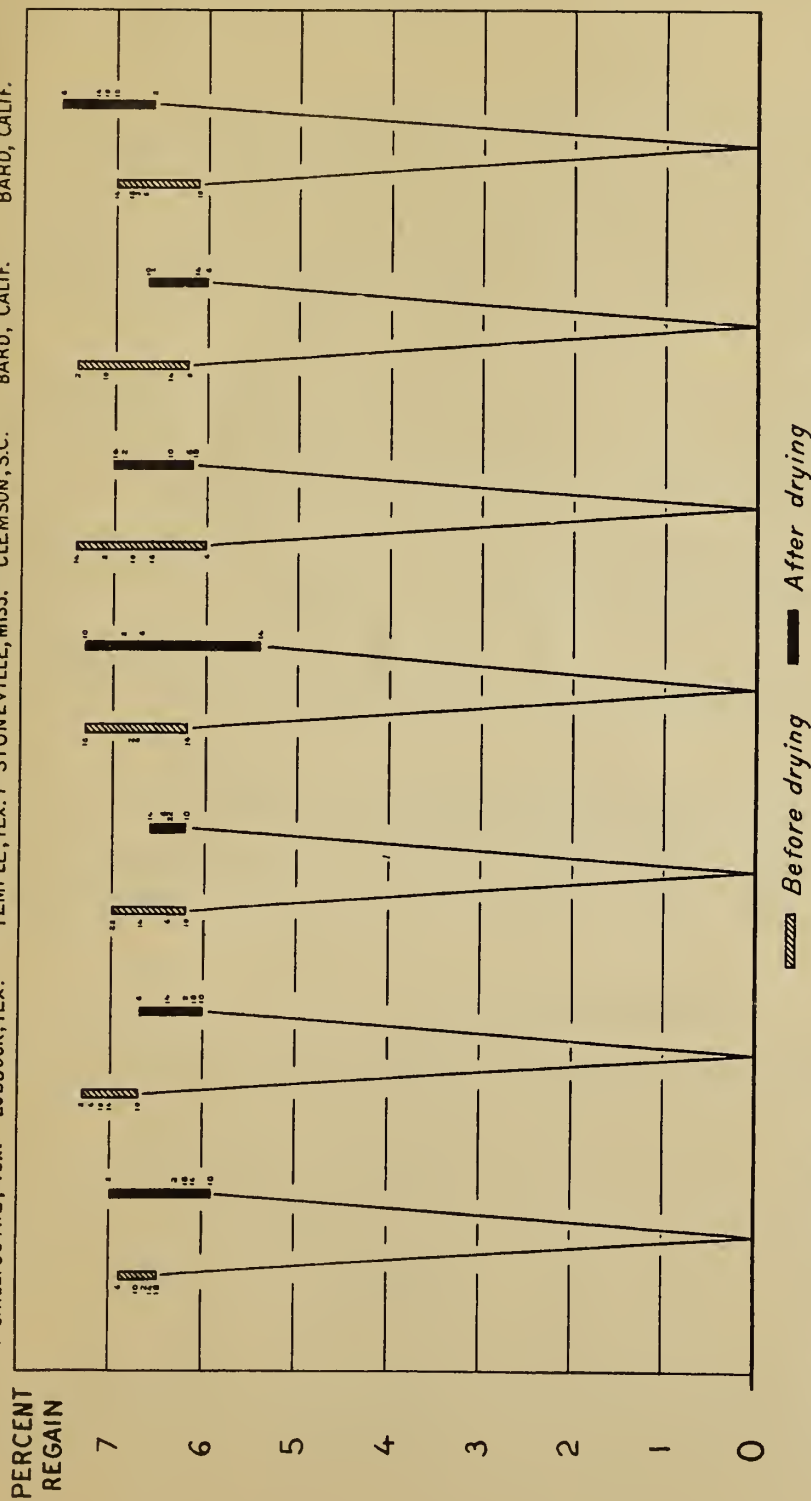
Moisture Regain of Samples Exposed in Field for Selected Periods

To discover whether the ability to absorb moisture was affected by exposure, that is, whether samples picked before exposure were able to absorb more or less moisture than those picked after long exposure in the field, or whether any one series of cottons as compared with any other showed such a tendency, a series of moisture tests was made. Exposure affected the color of the cottons: did it also affect the moisture absorbing qualities?

For this test every fourth sample - that is, cotton picked every fourth week for each of the seven cottons received - was used. Small samples, weighing about 8 grams, were placed in small tin cans under constant humidity and temperature in the Washington laboratories (62 wet bulb, 70° relative humidity) to condition. There they remained for approximately three days. The covers of the individual cans were then put on and sealed, and the entire lot was shipped to the moisture-testing laboratory of the Experimental Ginning Plant at Stoneville, Miss. There 9/ the samples were weighed, dried to a bone-dry condition, reweighed, and returned to Washington in sealed containers. At the Washington laboratories the samples were again exposed to conditions of constant humidity and temperature for about three days and were then reweighed. Two lots of samples were sent to Stoneville in order to see that the readings checked.

In Figure 7 the results of the test are given. The moisture regain was figured on a basis of a bone-dry weight of 100 per cent. The black bars on the chart indicate the range of moisture regains found for different samples of the same cotton. The numbers on each bar indicate the weeks that the cotton remained in the field before picking. They are placed in the order of percentage regain, and, as may be seen, give no evidence of any regularity of change in ability to take up moisture. Some samples that remained in the field all winter showed more ability to take up moisture than did samples that were picked early; in other cases the influence of the time factor seemed to be just the reverse. Nor does there seem to be any real difference among the series of samples used; they were all about 6 to 7 per cent. The only item that does show up is the fact that the regain figured on the weight after drying, with the possible exception of Pima, is slightly less than it is when figured on a basis of weight before drying.

9/ These tests were made under the direction of George W. Pfeifferberger, in charge of the moisture tests at Stoneville, Miss.



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FIGURE 7 - MOISTURE REGAIN OF SAMPLES OF COTTONS EXPOSED IN THE FIELD FOR SELECTED PERIODS OF TIME.

THE FIGURES, WHICH REPRESENT THE NUMBER OF WEEKS OF EXPOSURE WITHIN EACH KIND OF COTTON, ARE ARRANGED IN THE ORDER OF REGAIN. ALL SAMPLES WERE CONDITIONED FOR WEIGHING BEFORE AND AFTER DRYING IN THE OVEN. RESULTS: (1) THERE IS NO REGULARITY OF CHANGE IN MOISTURE CONTENT WITH LENGTH OF TIME THAT THE SAMPLES ARE EXPOSED IN THE FIELD; (2) THERE DOES NOT SEEM TO BE ANY REAL DIFFERENCE OF MOISTURE CONTENT AMONG THE COTTONS USED; AND (3) THE REGAIN FIGURED ON THE WEIGHT AFTER DRYING IN THE OVEN IS SLIGHTLY LESS THAN IT IS WHEN FIGURED ON THE BASIS OF WEIGHT BEFORE DRYING.

The rate of regain on several of these cottons is also being studied, but up to the present the results have shown nothing of importance. When the work on this subject is completed it may be that there will be more conclusive information.

Weather Data

No detailed study has yet been made regarding the relation of weather to the color of cotton. Records of rainfall and temperature were kept at each station where the cotton reported upon was grown. The amount of rainfall has been cumulatively plotted on an inverted scale in Figure 1. The inversion was made because there seems to be, in most cases, a high correlation, between increasing amounts of rainfall and decreasing brightness, a relation which is readily apparent when the scales selected were used.

The maximum and minimum temperatures at each station are available for the information of any student who may need it for further study of this problem. There is no evident correlation with color change, yet further studies, after another year's work is completed may throw more light on this point.

The hours of sunlight during the period of exposure will be used in studying weather effect insofar as such records are available.

The weather data for the California-Arizona district came from Yuma, just across the State line from Bard, Calif., the station from which the cotton was supplied.

COLOR STABILITY OF COTTON AFTER EXPOSURE TO HEAT

The next problem was to study what happens to these cottons in the laboratory. Are they, in the state in which they are picked, stable or unstable in color?

At Room Temperature

After the first measurements of each cotton were made, the samples were carefully filed in boxes that would keep the measured faces from contact with other samples. The boxes were kept in the color laboratory where the temperature varied with the degree of heat in the building. Once a week, for approximately six months, these samples were put under constant humidity and temperature overnight, and were measured for color in the laboratory on the next day. After the first six months the time between measurements was increased to two weeks and then to four weeks. At the time this preliminary report is written the samples have all been periodically measured for ten weeks, most of them for twenty weeks, and many of them for very nearly a year. Such measurements will continue for a period of several years, to give a basis for understanding what time will do to the color of cotton exposed to no unusual conditions. Results for the first 10 or 20 readings are shown in the series of seven graphs at the left of Figure 8.

The heavy solid line on each of the graphs in this figure shows the general trend of color change caused by exposure in the field. The top of the line represents the color of the first samples received of each cotton. As the cottons were picked week by week the resulting samples lost much of their creaminess and became darker. These trend lines are smooth curves drawn to represent the changes shown by the individual samples in Figures 2 and 3.

The short arrow-headed lines drawn from this series of charts in the column marked "Room Temperature" represent the amount and kind of color change that seems to take place on the average for samples stored at room temperature. The first arrow on each short line represents the average change in measurement 10 weeks after the first measurement was made. The second arrow on the same chart represents the difference in measurement 20 weeks after the first measurement was made. The short lines themselves, as they are attached from the top of the heavy solid line to the bottom of it, indicate the relative time of exposure: the further down on the line the arrow projects, the later the sample was picked. There is a very slight but quite definite trend. Samples stored at room temperature lose a trace of their original brightness; most of the samples also lose a trace of their original creaminess. Whether this depends upon the original color of the cotton (that is, whether creamy or white cotton) and whether the small amount of handling as the cotton is measured time after time is the cause of this slight change, are still questions. After work has been done on samples that have been in storage two or more years, the results of this phase of the study will be more conclusive than they are now.

At 133° F., Lint and Seed Cotton, for Three Months

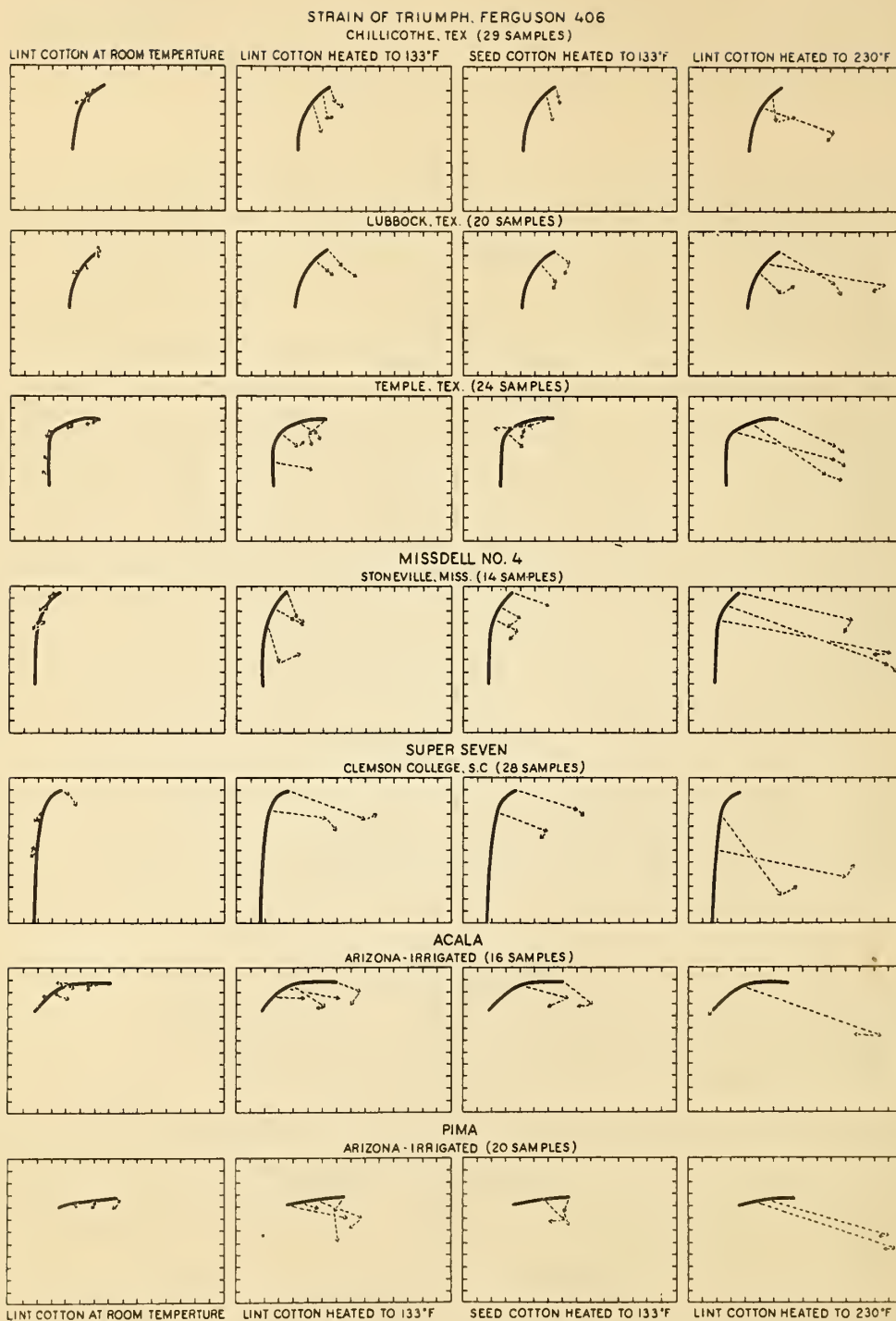
Lint cotton - In general practice cotton is subjected to many other conditions of temperature besides room temperature, even to such extremes as hot tin roofs in the summer or unheated warehouses in freezing weather. Two studies were therefore outlined - one at high temperature and one at low temperature.

As a part of the high-temperature study, a series of samples, picked four weeks apart, was selected for testing after subjection to heat. Half of each sample was delinted by hand (that is, the fibers were separated from the seed by hand); the other half was kept in the seed.

A paraffin embedding oven was available in the laboratory which could be controlled at 56°C, equal to about 133° F. The samples were placed in this oven where they remained for three months. At the end of that time they were removed, conditioned overnight at constant temperature and humidity, and measured in the color laboratory.

In the second vertical column of Figure 8, the first arrow on the dotted lines indicates the amount of color change that took place compared with the original color of the samples. All of the samples became yellower than they were originally, but they did not become equally yellow. The three Texas samples seemed to gain about the same amount of yellow color. The Super Seven cotton from South Carolina gained considerably more color than the others. It may or may not be significant that this cotton was considerably whiter in

(-turn to page 20-)



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FIGURE 8 - COLOR STABILITY UNDER VARIOUS CONDITIONS OF HEAT.

(SEE LEGEND ON NEXT PAGE.)

Legend for Figure 8.

These graphs are drawn to the same scale as those in Figures 2 and 3. and color changes are indicated in the same way: all light colors are at the top of each chart with the darker colors at the bottom; all yellow colors are to the right of each chart with the whiter and grayer colors to the left.

The solid black line indicates the general trend of color change due to exposure in the field. Cottons that opened about the same time were picked week by week, and the color trend, as these cottons changed from bloomy white cottons to darker, lower grades, is shown by the solid black lines. The different cottons vary in creaminess at the start, although the brightness is about constant at the start. The Acala and Pima cottons show little brightness change, doubtless because of lack of rainfall and the frequent wetting of the bolls which took place in the other cottons.

In the first vertical series of graphs the cottons are exposed to room temperature only. The individual weekly samples were measured week by week, and the instability trend as shown by the 10th and 20th week's measurements is indicated by the short arrowheads. The general trend was towards a slight loss of color. There is also a slight loss in brightness.

The trend of change shown in the second series of vertical graphs indicates one which is caused by the heating of certain of the lint samples for three months at 133°F in a paraffin embedding oven. The first arrow on each line indicates the relative change from the original color which was apparent immediately after the cotton was removed from the oven. The second arrow indicates a measurement made 10 weeks later. In general, this series of charts shows a distinct increase or yellowing of the cotton, with a continuation of the yellowing as the cotton remains in the laboratory at room temperature.

The third series of graphs represents a test for a series of samples, similar in every respect except that they were not removed from the seed. The general trend of color change for seed cottons heated to 133°F is about the same as that of the lint cotton. Any difference between the two series of graphs seems to indicate that the cotton that was delinted before storing at a high temperature becomes even more yellow than the seed cotton that had not been similarly stored.

The fourth series of graphs indicates the change caused by heating to a higher temperature. (The samples were not scorched.) The cottons were delinted and placed in a conditioning oven where they remained for approximately five days at about 230°F. It is apparent that heating to such a temperature induces a high color in the cotton, which, even after 10 weeks at room temperature, tends to increase slightly.

the beginning than the Texas cottons. The second arrow indicates any additional change that took place within the next 10 weeks of storage at room temperature.

Seed cotton. - At the same time, and in the same oven, seed cotton of each of the lint lots. was heated. It was taken out, the fibers were pulled off the seed by hand, and measured in the same way that the lint cotton was measured.

The results are indicated in the third vertical column on Figure 8. The general trend of color change for the seed cotton is about the same as it was for the lint cottons. If there is a difference it leans toward the lint samples, that is, the lint cottons seem to have gained slightly more chroma than the cotton heated in the seed. The second arrow indicates a measurement taken 10 weeks after the cotton was removed from the oven.

The change in brightness indicated on all of these charts accompanies the change in chroma. In other words, as samples become a deeper yellow, they also become darker. This is in agreement with results found in practical classing work, for a Good Middling White cotton is brighter than a Good Middling Yellow Tinged cotton which, in turn, is brighter than a Good Middling Yellow Stained Cotton.

At 230° F, Lint Cotton, for Five Days

The cottons heated at 133° F showed enough color change to make it seem desirable to know what would happen if the cotton were subjected to a higher temperature. A similar series of samples was delinted by hand and placed in a conditioning oven at 230° F, the highest heat that could be regulated in this oven. There they remained for five days. Then they were removed from the oven, conditioned overnight, and measured in the color laboratory. Without exception, the samples gained considerably more color than those heated at 133° F. Many of the samples came out with the color of Yellow Stained cotton. All of them had at least as much color as the heavy Spotted or Yellow Tinged grades. There seemed to be a difference in the amount of color that the different kinds of cotton gained. The yellower Texas cottons did not, on the average, gain as much as did the whiter cottons. The white cotton from the Mississippi Delta gained the most color. The one sample tested of Acala also gained a great deal of color.

Measurements 10 weeks afterwards indicated a possible slight continued increase in color for most of the samples - at least there was no trend toward loss of this yellow color in that length of time.

OTHER TESTS

At the time this report is written a series similar to this one (that was heated) has been subjected to varying degrees of refrigeration. Another

series has been exposed through the late spring and summer months to sunlight through a series of color filters, some of the samples being regularly moistened.^{10/} The results will be reported at a later date.

As any study of color stability in cotton must be carried on over a period of years, the information available as a result of this year's work is merely preliminary in nature. During the 1932-33 season, samples from Texas, under the cooperative agreement of 1931-32, will be received from Chillicothe, Lubbock, and Temple. Will these samples change in the same way? Presumably they will show the same general tendencies, yet varying weather conditions may give different amounts or degrees of change. Already some of the first samples have been received. There is a small but evident difference. Samples from Stoneville (two varieties, Missdel #3 and #4) will be included in the 1932-33 material. Two year's material on Super Seven has already been received from Clemson. The samples of irrigated cotton have been omitted from 1932-33 because the differences and comparisons for 1931-32 seem to be evident enough for the present. It is probable that several phases of this stability study will be gone into more intensively at a later time. At present it seems more important to survey the general trends of stability than to study the details.

Before the work is finished it will be necessary to make tests regarding the percentage of thick and thin walled fibers, and weight per unit length of samples exposed in the field for varying lengths of time. Information so gained should show conclusively whether samples exposed to weather damage for several months before picking are injured or changed in respect to the percentage of thick and thin walled fibers and in weight per unit length. Careful studies of the relation between weather and the properties of weather-exposed cotton are necessary. Examinations should be made regarding exposure to ultra-violet light, and regarding the fluorescing powers of the different cottons. Samples should be studied in polarized light; they should be exposed to heat, with humidity controlled; microscopic examinations should be made for fungi, spots, and stains. All of these studies should be made before the work is considered complete. Chemical analyses to discover causes of these changes comprise still another series of tests.

SUMMARY

To determine the kind and amount of color change in cotton and to study the extent to which other factors are related to these changes, a series of seven cottons from different parts of the Cotton Belt was examined. One cotton was examined for the 1931 season; six other cottons were added for the study of 1932 cottons.

As the cotton remained open and exposed in the field the color and grade were lowered. The chief points are that: (1) Upland cottons at time of opening were fairly constant in brightness; (2) upland cottons at time of opening varied greatly in amount of creaminess or chroma; (3) the creamier cottons held their brightness better than did the whiter cottons, and (4) in most cases there seemed to be a high correlation between amount of rainfall and change in brightness.

10/ Because of better laboratory facilities these exposures have been made through the courtesy of the Boyce Thompson Institute at their laboratories in Yonkers, N. Y. by Mrs. Wanda K. Farr, a member of the Division of Cotton Marketing stationed at that Institute.

Data presented regarding color differences shown by cottons opening early and late in the season are an inadequate basis for conclusions regarding the effect of time of opening.

The color of cottons opening at or after a killing frost are compared with the color of other cottons. The data in this case are not sufficient for making definite conclusions.

Length and strength tests on samples of the seven cottons are presented. No definite trend of change with time of exposure is shown. A relation does seem to exist between the long cottons and the strong ones. Moreover, the cottons that opened after frost are, in ^{almost} all cases, longer than other cottons of the same series; they are also stronger than other cottons picked late in the season from the same field.

The percentage of moisture regain gives no evidence of any regularity of change in ability to absorb moisture within any single series, nor does there seem to be any real difference among the series of samples used.

Cotton kept at room temperature shows very little change in color in 10 or even in 20 weeks. The samples did lose a trace of their original brightness, and most of them lost a trace of their creaminess.

Cottons kept at a temperature of approximately 133° F for a period of three months gained creaminess. Seed cottons as well as lint cottons were tested, with little difference in result. The difference that did exist indicated that the cotton heated in the seed did not gain, on the average, quite so much color as did the cottons that were removed from the seed before heating.

Cottons heated at 230° F for several days showed a still greater increase in amount of yellow color; some of the cottons which were white in the beginning gained enough color to make them as yellow as the Yellow Stained grades. The White cottons seemed to gain more color than those that were originally creamy.

Other tests, including refrigeration and tests under filters of selected wave lengths, are being made. Still other tests are planned. It is planned to make results available as rapidly as the tests are completed.

This first preliminary report gives the results to date of a study of stability of color in raw cotton and studies of associated factors.

* * * * *

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

Groups organized for cotton improvement eligible for free classing and market news,
number, membership, and acreage, by States, 1939 and 1940

| State | Organized groups | | Members | | Members per group | | Acreage planted | | | Acreage planted by groups as a percentage of total 1 | | |
|----------------|---------------------|--------|---------|---------|----------------------|-------|--------------------|-----------|------------------|---|------|------|
| | | | | | | | Adopted variety | | All varieties | | | |
| | 1939 | 1940 | 1939 | 1940 | 1939 | 1940 | 1939 | 1940 | 1939 | 1940 | | |
| | Number | Number | Number | Number | Acres | Acres | Acres | Acres | Percent | Percent | | |
| Alabama | 93 | 170 | 6,026 | 13,068 | 65 | 77 | 36,986 | 225,089 | 98,844 | 234,185 | 4.7 | 11.2 |
| Arizona | 27 | 41 | 337 | 1,200 | 12 | 29 | 46,046 | 129,901 | 46,446 | 154,812 | 25.8 | 68.2 |
| Arkansas | 90 | 103 | 4,997 | 6,326 | 56 | 61 | 88,325 | 119,025 | 92,547 | 125,891 | 4.2 | 5.8 |
| California | 14 | 22 | 1,409 | 4,170 | 101 | 190 | 112,139 | 244,473 | 112,150 | 244,473 | 33.6 | 64.6 |
| Florida | 10 | 20 | 242 | 357 | 24 | 18 | 2,967 | 6,433 | 2,993 | 6,533 | 3.3 | 8.9 |
| Georgia | 76 | 129 | 5,984 | 10,321 | 79 | 80 | 113,203 | 188,699 | 118,300 | 196,399 | 5.7 | 9.8 |
| Louisiana | 31 | 50 | 1,444 | 5,301 | 47 | 106 | 35,234 | 119,543 | 36,632 | 120,679 | 3.2 | 10.1 |
| Mississippi | 76 | 124 | 11,455 | 13,596 | 151 | 110 | 127,020 | 219,693 | 131,980 | 229,772 | 5.0 | 8.6 |
| Missouri | 9 | 15 | 320 | 1,115 | 36 | 74 | 14,408 | 46,183 | 14,689 | 49,943 | 3.9 | 12.6 |
| New Mexico | 23 | 26 | 2,482 | 3,201 | 108 | 123 | 92,128 | 108,223 | 92,128 | 108,529 | 93.1 | 99.6 |
| North Carolina | .55 | 87 | 3,434 | 4,846 | 62 | 56 | 48,073 | 79,003 | 50,771 | 81,143 | 6.5 | 9.8 |
| Oklahoma | 108 | 139 | 9,962 | 15,436 | 92 | 111 | 355,428 | 446,439 | 358,328 | 457,936 | 19.3 | 23.7 |
| South Carolina | 10 | 53 | 474 | 4,908 | 47 | 93 | 8,539 | 64,256 | 10,416 | 73,022 | .8 | 5.7 |
| Tennessee | 8 | 12 | 257 | 653 | 32 | 54 | 3,625 | 8,996 | 5,146 | 9,264 | .7 | 12.4 |
| Texas | 287 | 581 | 15,544 | 43,492 | 54 | 75 | 628,558 | 1,851,781 | 770,371 | 2,013,478 | 8.6 | 22.5 |
| Virginia | -- | 1 | -- | 226 | -- | 226 | -- | 2,391 | -- | 2,457 | -- | 7.9 |
| All other | 1 | -- | 32 | -- | 32 | -- | 3,560 | -- | 3,560 | -- | 16.2 | -- |
| Total | 918 | 1,573 | 64,399 | 128,216 | 70 | 82 | 1,766,289 | 3,860,128 | 1,945,301 | 4,103,516 | 7.9 | 16.4 |

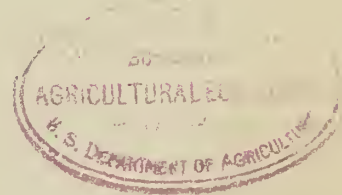
1/ Acreage of all varieties planted by group members divided by the total acreage planted in each State and in the United States. United States acreage in cultivation on July 1, as reported by the Crop Reporting Board on July 8, 1939 and 1940.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

COLOR STABILITY IN RAW COTTON
II. STORAGE TESTS

By Dorothy Nickerson
Color Technologist

Washington, D. C.
October 1941



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COLOR STABILITY IN RAW COTTON

II. STORAGE TESTS ^{1/}

By Dorothy Nickerson, Color Technologist,
Agricultural Marketing Service

Any lack of stability in elements of quality is a serious problem in standardization, and because color is a major factor in the standardization of raw cotton, color studies have been carried on for several years in the Agricultural Marketing Service in connection with cotton standardization and grading problems.

The present study was undertaken because periodic reports received in the Department regarding changes in the color of baled cotton held in storage indicated a lack of color stability in that cotton. There were times when a considerable change in grade was reported. But because the grading of cotton is a fine art — that depends upon a grader's skill, his accurate eye and keen color memory — rather than a science which depends upon measurements that can be repeated, such reports have never been accompanied by information from which it might be possible to ascertain the nature and extent of the reported color change.

In contrast to reported increases in color and such other changes as cause cottons to be graded Spotted instead of White after several years of warehouse storage, tradition and experience indicate that many spotted cottons do not retain their spots under storage. In fact, although there have been many requests for the development of physical standards for grades of spotted cottons, the Department of Agriculture has been unwilling to attempt this for no one has been able to tell which cottons will change, or how much change is to be expected.

As a beginning towards gathering information to answer some of these questions, a very simple sort of study has been made. Results after a 5-year period of storage for 12 different cottons, are definite in several respects: first, under some conditions cottons in storage do increase in color by an all-over tinged effect; second, spots in white or light spotted cottons are very unstable, tending generally to decrease in number and size with increased storage of the cotton. The degree and kind of change are shown in the tables and charts included in this report.

Previous Color Stability Studies

In 1933 the first report on studies of stability of color in raw cotton was published.^{1/} It had to do primarily with the effect of exposure, being based on results of a cooperative study of the color change which resulted when cotton bolls, after opening, were left unpicked and exposed in the field to natural

^{1/} This is Part II of a study on color stability in raw cotton. The first report -- Studies of Stability of Color in Raw Cotton -- by Dorothy Nickerson and Leona Dilworth Milstead, was mimeographed and issued as a preliminary report by the Bureau of Agricultural Economics in 1933. (22 pp.; 8 figs.)

weather conditions, only part of the bolls being picked each week. Results of the study showed that Upland cottons at the time of boll opening are fairly constant in brilliance, but vary greatly in degree of creaminess or chroma;^{2/} that the creamier or yellower cottons hold their brilliance under exposure to weather better than do the whiter cottons; and that a high correlation exists between the amount of rainfall and change in brilliance of the cotton after exposure. Samples of the cottons in this test, when kept at room temperature after picking, showed little change in color in 10 or even 20 weeks. When kept at high temperature (both on and off the seed) they increased in chroma. An extreme change occurred with the whiter cottons, the gain in chroma when heated in a drying oven for several days at 230°F being enough to make them as deep a yellow as the old yellow-stained grades.

Since the publication of the first report, collection of data concerning color change in the cottons used in the original test has been continued. Samples of these cottons, kept for several months under refrigeration^{3/} at 5°, 10°, and 15°C, showed no marked color change. Samples of the same cottons were exposed, in a greenhouse,^{3/} to sunlight through filters selected to isolate several wavelength bands in the visible spectrum. Results showed that samples exposed under yellow and orange filters seemed to change more than those exposed under green and blue filters. This, however, may have been the result of increased heat due to the relatively higher infra red transmission by the yellow and orange filters, rather than to change caused specifically by particular wavelength bands of the visible spectrum.

Present Test

In regard to the present test it was decided in the laboratory, to survey the job on a small enough scale so that studies could be handled without new funds or large supplies of cotton. Obviously, without funds allocated to a special color stability project, bales stored in various types and locations of warehouses could not be studied. Since color change is a problem in standardization, and since cotton grade standards are prepared in a definite size of package, it was decided to use this package for the test. Replicate boxes were prepared with 12 samples in each. Boxes were strapped in groups of three; the top and bottom boxes were sealed tight, and the middle box was

^{2/} Color may be described in terms of three visual qualities or dimensions -- hue, brilliance, and chroma.

Hue is the name of a color, as red, yellow, green, etc.

Brilliance is defined as the degree of lightness or darkness on a scale of visually equal steps from black at the 0 end of the scale to white at 10. Lightness is synonymous with brilliance.

Chroma is defined as the strength or intensity of color -- its degree of departure from a gray of the same brilliance. The scale of chroma begins at gray, which is 0 chroma, and extends outward by increasing numbers. A very strong yellow or a strong red may be as much as /12 or /14 in chroma, but raw cotton, even in a deep yellow stain, will seldom extend beyond /4 in chroma.

^{3/} In 1932, at Boyce Thompson Institute through the courtesy of Dr. John A. Arthur and Mrs. Wanda K. Farr.

punched with air holes just below the cover so that there could be some circulation of air. It was intended that the top box would be returned for measurement in 2 years, and the other two boxes of each set after 5 years' storage. Groups of these boxes were sent to 15 widely scattered points throughout the country for storage in sample rooms and warehouses. Lists of the 12 cottons used (6 varieties, 1st and 2nd pickings of each) and the 15 storage points, are given in tables 1 and 2.^{4/}

Table 1. - Cottons used in storage test

| Code letter | Variety | Locality grown | Harvesting | | Moisture content | Staple | Grade ^{1/} | Color measurement | |
|-------------|-----------------|-------------------|------------|-------|------------------|--------|---------------------|-------------------|----------------|
| | | | Date | Stage | | | | Brilliance | Chroma |
| A | Wilson type | Wilson, Ark. | 9/18 | 1st | 9.8 | 15/16 | 5 | 8.74 \pm .04 | 1.61 \pm .07 |
| | | | 10/7 | 2nd | 7.9 | 31/32 | 5 | 8.69 \pm .05 | 1.56 \pm .05 |
| B | Cook 307-92 | Prattville, Ala. | 8/31 | 1st | 12.5 | 7/8 | 5 | 8.57 \pm .05 | 1.72 \pm .06 |
| | | | 9/24 | 2nd | 10.5 | 7/8 | 6 | 8.50 \pm .06 | 1.63 \pm .07 |
| C | Stoneville | Stoneville, Miss. | 9/2 | 1st | 10.3 | 1-1/8 | 5 | 8.82 \pm .05 | 1.53 \pm .07 |
| | | | 10/4-7 | 2nd | 7.4 | 1-3/32 | 6 | 8.67 \pm .09 | 1.43 \pm .05 |
| D | Kasch | Edray, Tex. | 7/22 | 1st | 10.8 | 1-1/32 | 5-10 | 8.69 \pm .07 | 1.96 \pm .06 |
| | | | 8/8 | 2nd | 8.0 | 15/16 | 5 | 8.71 \pm .05 | 1.90 \pm .07 |
| E | Acala (Shafter) | Sacaton, Ariz. | - | 1st | - | 1-1/16 | 3 | 8.88 \pm .04 | 1.77 \pm .09 |
| | | | - | 2nd | - | 1-1/32 | 4-10 | 8.80 \pm .08 | 1.81 \pm .09 |
| F | Pima | Sacaton, Ariz. | - | 1st | - | 1-9/16 | #2 | 8.30 \pm .09 | 2.81 \pm .16 |
| | | | - | 2nd | - | 1-9/16 | #1-1 $\frac{1}{2}$ | 8.37 \pm .04 | 2.67 \pm .12 |

Cottons A - D were supplied from the U. S. Ginning Laboratory at Stoneville, Miss.

Cottons E and F came from the U. S. field station at Sacaton, Ariz.

^{1/} Grades of Upland cottons are white except where noted at 10's (light spotted); grades of Pima are based on American-Egyptian standards.

These cottons were of the 1935 crop. They were prepared and shipped out in the spring of 1936. Each lot of the 12 cottons used in preparing the replicate boxes was carefully inspected by the Appeal Board of the Service to be sure that it was of the same grade throughout, and representative samples were measured in the Color Measurements Laboratory to be sure that the color was regular. After the boxes were made up, each was photographed, all spots were circled on the photographs, and each box and photograph was reviewed by the Appeal Board and the Color Laboratory for duplication of grade and a count was made of the number of spots before the boxes were shipped.

^{4/} Our thanks are hereby expressed to the several commercial warehouses who cooperated by storing test boxes and to those in charge of the Division's field classification offices who cooperated by storing samples in their classing rooms.

Table 2. — Storage locations

| Code No. | Location | Stored at | | Weather data ^{1/} April 1936 — April 1941 | | |
|----------|--------------------|-----------------|-----------------|---|------|---------------------------|
| | | | | Average temperature | | Average relative humidity |
| | | Office | Warehouse | Max. | Min. | |
| 1 | New Bedford, Mass. | | ✓ | 59.0 | 42.2 | 57 |
| 2 | New York City | ✓ | ✓ | 60.6 | 45.7 | 58 |
| 3 | Washington, D. C. | ✓ ^{2/} | | 65.2 | 47.8 | 53 |
| 4 | Charleston, S. C. | ✓ ^{3/} | ✓ ^{4/} | 73.6 | 59.1 | 59 |
| 5 | Atlanta, Ga. | ✓ | ✓ | 71.7 | 51.2 | 55 |
| 6 | Memphis, Tenn. | ✓ | ✓ | 70.5 | 54.1 | 57 |
| 7 | Mobile, Ala. | ✓ | ✓ | 76.2 | 58.7 | 58 ^{1/} |
| 8 | New Orleans, La. | ✓ | ✓ | 77.5 | 62.1 | 61 |
| 9 | Austin, Tex. | ✓ | ✓ | 78.1 | 57.6 | 54 |
| 10 | Dallas, Tex. | ✓ | ✓ | 75.1 | 56.0 | 53 |
| 11 | Galveston, Tex. | ✓ | ✓ | 74.5 | 64.7 | 70 ^{1/} |
| 12 | Houston, Tex. | ✓ ^{5/} | ✓ | 77.8 | 60.7 | 57 ^{1/} |
| 13 | El Paso, Tex. | ✓ | ✓ | 77.0 | 52.5 | 32 |
| 14 | Phoenix, Ariz. | | ✓ | 85.7 | 58.0 | 29 |
| 15 | San Pedro, Calif. | | ✓ ^{6/} | 73.6 | 55.9 | 48 |

^{1/} Weather data from Climatological Data, U. S. Weather Bureau. Relative humidity is given for near-noon observations. Data for Houston and Galveston taken at 8:00 a.m. are in reverse order: Galveston 84, Houston 86. Humidity data for Mobile at noon available for only 3 years out of the 5-year period.

^{2/} At the beginning of this study it was intended that samples would be kept in the laboratory at controlled conditions of temperature and humidity, but laboratories were moved within a year and controlled conditions were not established in new laboratories until too late.

^{3/} One box (of three) returned empty.

^{4/} Three boxes disappeared in warehouse.

^{5/} Three boxes destroyed by fire.

^{6/} One box returned empty.

In the spring of 1938 one box was recalled from each storage place. The boxes were opened, and the samples were compared visually by the Appeal Board and were measured for color in the laboratory. The samples were compared with the photographs to see whether the number and the size of spots had changed. The Appeal Board found evidence of change in the 2nd picking of Acala cotton. Color readings indicated that there was some change in the cottons. Cottons

stored at certain Texas points tended to be a trifle more yellow than those stored elsewhere. Records of spots showed that many of them had disappeared. But since none of these differences was large, it seemed best to wait to confirm the results until after longer storage.

In the spring of 1941 the remaining boxes were recalled. Again, the samples were visually compared, spots were counted and checked with the original photographs, and all samples were measured for color. The average results are shown graphically in figures 1-6.

Average Results

Figure 1 shows color measurements, figure 2 shows increase in yellowness as found by classer when comparing with the whitest box of the series, and figure 3 shows change in number of spots — all as they relate to the varieties of cottons included in the test, a 1st and 2nd picking of each. Color measurements are made in terms of hue, brilliance, and chroma. ²

Because the hue of Upland cottons is so nearly constant, only brilliance and chroma are plotted in the color measurements shown in figure 1. As the illustrations show, there is a very considerable original difference between some of the varieties. The outstanding and most important difference on the chart, regardless of the original color, is the increase in chroma for all cottons that were stored, the difference generally being accompanied by a decrease in brilliance. Except for the Acala cotton (E), the chroma increase is not great for 2 years, but after 5 years' storage the increase, as compared with the original chroma, is marked in all cases. A difference of more than 0.15 is significant. The direction of change is the same in all cases, but the 2nd picking of rain-grown cottons did not seem to change quite as much as the 1st picking. The greatest change is shown by the Acala cotton (E), the least by the 2nd picking of the Mississippi cotton (C).

The direction and relative amount of change shown in the chroma plot in figure 1 is generally substantiated by the data for visual comparisons in figure 2. The data for this chart were based on visual comparisons made by the Appeal Board and by the author. The whitest box in the series was set up as a key box, and each of the other boxes were compared with it, sample by sample, for each of the 12 positions in each box. The index for scale of judgment is: No difference, 0; slightly yellower, 1; yellower, 2; yellower-plus, 3, much yellower, 4; slightly whiter, -1; whiter, -2; etc. A judgment of "possibly yellower" is placed between 0 and 1. The boxes were judged in no particular order, and no one knew where the box had been stored until after the judgments were made. From figures 1 and 2, the over-all change in color by varieties may be studied. All the varieties of cottons increased in color under storage, but some increased more than others. The base line for figure 2 is the same as the top of the solid black base in figure 1. Keeping this in mind it can be seen that the maximum differences are for the Acala cottons, particularly the 2nd picking, and the minimum differences are for the 2nd picking cotton grown in Mississippi.

In figure 3 only spots are considered. The number of spots in each sample of each box was counted at the beginning of the test and a penciled ring was made on the photograph around each of the spots. When the cotton was returned in 1938 each box was compared with an actual-size photograph of it taken in 1936. When the spot had disappeared, the ring was canceled on the photograph. If spots had developed in places not previously marked, they were indicated. The same procedure was followed in 1941 for all the boxes in the test, for those returned to Washington in 1938 as well as for those returned in 1941. It should be remembered that all the cottons in this test were originally graded either white or very light spotted. Therefore there were not many spots on the surface of any sample, but those that appeared varied in number from 0 to 8.^{5/} Because the relative number of spots for each sample varied a great deal, and in order that relative amounts of change could be studied, the results were reduced to percentages.

As may be seen from figure 3, the relative number of spots decreased in all varieties, for both 1st and 2nd pickings. Within 2 years the rain-grown cottons (A-D) lost from 65 to 100 percent of their spots. Although there was an increase in number of spots in the cottons stored 5 years over the number of spots for cottons stored 2 years, in only one case was this increase important. This exception, which occurred in the 1st picking cotton from Mississippi, lost in 2 years 80 percent of the spots visible on the surface of its samples in 1936, but after another 3 years in Washington the same samples regained about 15 percent of their spots, making a net loss for 5 years of 65 percent as compared with an 80 percent loss for 2 years' storage. The 1st picking of Acala cotton had very few spots to start with, and lost practically all of these in 2 years. At the end of 5 years it had regained enough to show about a 35 percent net loss, as compared with the samples stored in the field for the entire 5 years of the test, which showed a 15 percent net loss during that period. The 2nd picking of Acala had more spots than any other cotton tested, and in 2 years' storage lost only about 50 percent of the spots, regaining very few by 1941. Those held in field storage for 5 years lost only about 15 percent of their spots. There seemed to be less change in the Pima samples than in the others, for in 2 years they lost only about 50 percent of their spots. For some reason, possibly a coincidence, after 5 years the Pima samples that were stored 2 years in the field then 3 years in Washington, seemed to regain more spots than those that were kept in field storage for 5 years.

From a study of figure 3, it seems reasonable to suppose that the change in number and intensity of spots during storage depends to a considerable extent upon the kind of cotton stored, possibly upon the conditions that surrounded its growth and harvesting, the degree of development, etc. Among the rain-grown cottons, it seems as if the 2nd picking lost a greater percentage of spots, and held that loss to a greater extent than did the 1st picking. But again this may be a coincidence. (All cottons in this test were hand picked.)

^{5/} See figures 9 and 11.

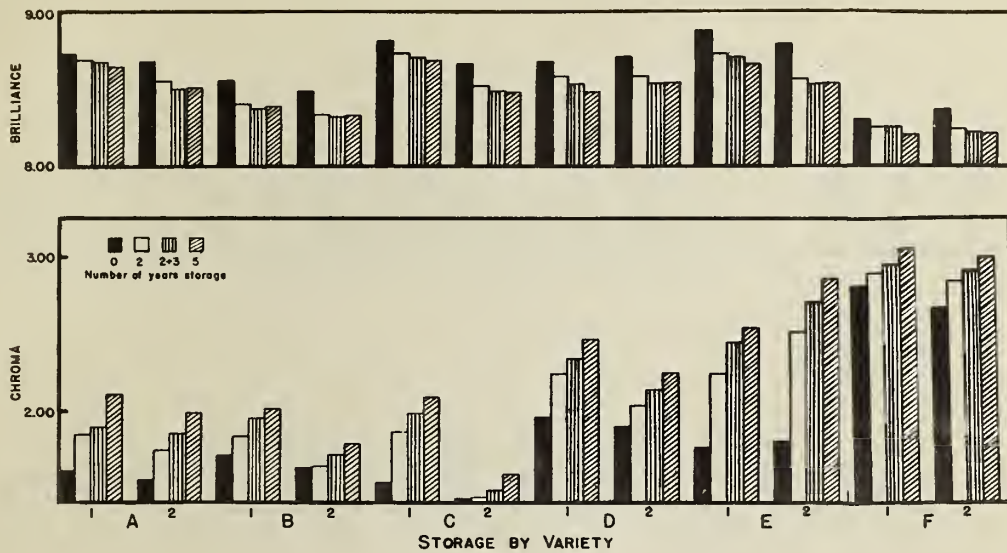


Figure 1. -- Color measurements before and after storage for each variety studied. Average of brilliance and chroma measurement for each lot, according to storage period.

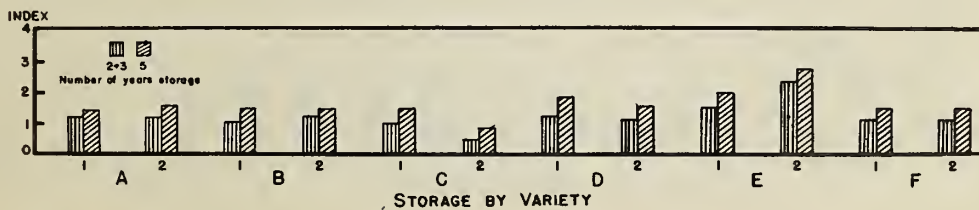


Figure 2. -- Increase in yellowness after storage by visual comparison to whitest box. Average for each variety studied, by storage period.

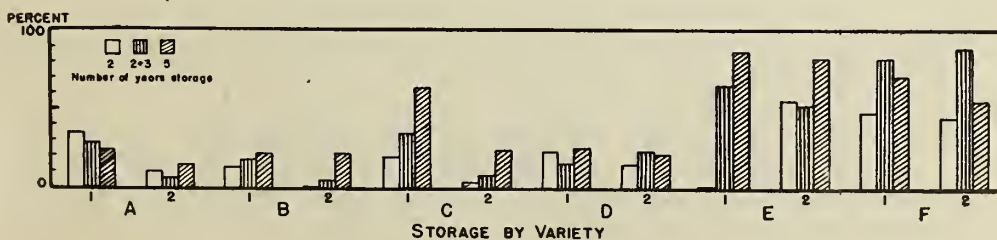


Figure 3. -- Number of spots after storage, shown as a percentage of number at beginning of test. Average for each variety studied, by storage period.

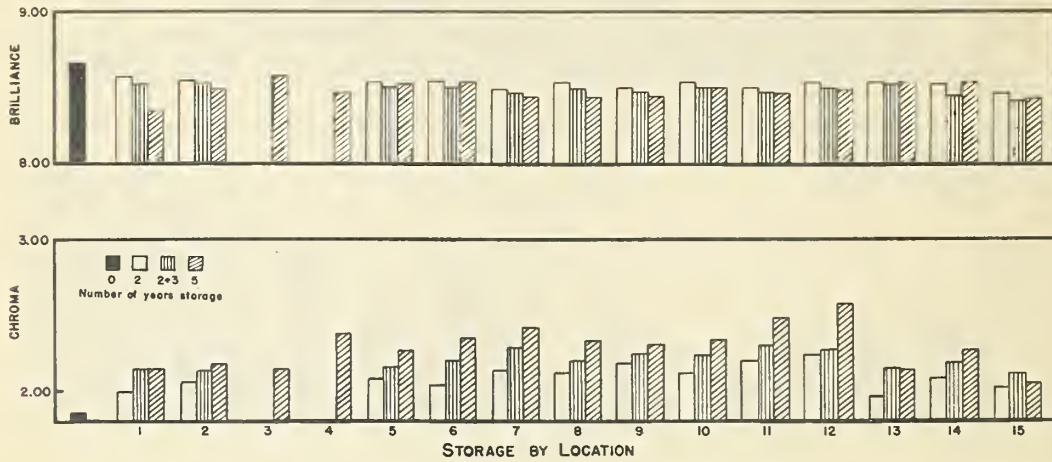


Figure 4. — Color measurements before and after storage. Average for each storage location studied, by storage period.

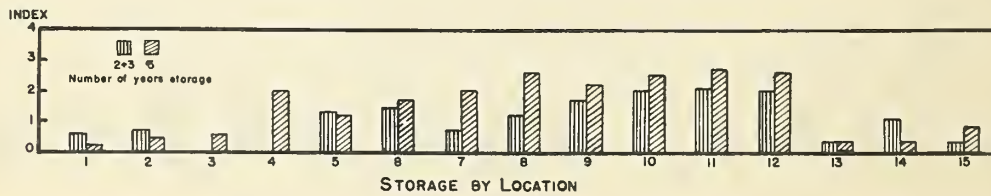


Figure 5. — Increase in yellowness after storage by visual comparison to whitest box. Average for each storage location studied, by storage period.

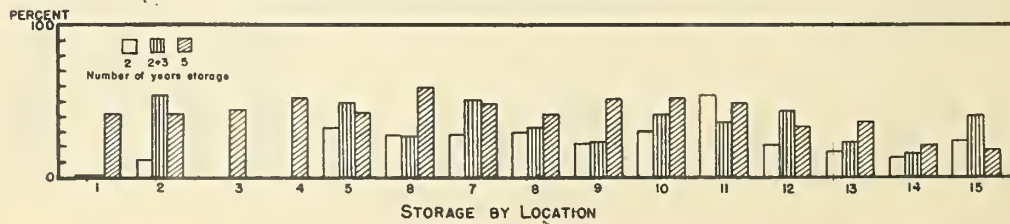


Figure 6. — Number of spots after storage, shown as a percentage of number at beginning of test. Average for each storage location studied, by storage period.

The next three figures (4-6) refer to average results for each of the storage locations, for it is of as much interest to discover whether place of storage causes a difference in color and number of spots, as it is to know whether various kinds and varieties of cotton cause such a difference.

Figure 4 is a parallel chart to figure 1, except that the original measurements are the same for each place and are therefore given but once in each part of the chart. As was true for figure 1, figure 4 shows a slight tendency toward a drop in brilliance when the cottons are measured after storage, but only in one case is that difference large enough to be significant. With this one exception, none of the differences are large enough to show that location of storage has any effect upon the brilliance quality of color. As for chroma, the story is quite different, for cottons held for 5 years in storage at such points as Houston (12), Galveston (11), and Mobile (7), show much greater color change than those stored at New Bedford (1), New York (2), Washington (3), El Paso (13), and San Pedro (15).

A chroma step of 0.15 is about as small as one can be sure of seeing when examining cottons; we might therefore call it a least perceptible chroma change for cotton. Taking this as a guide to the significance of the chroma data shown in figure 4, it is evident that for 2 years' storage only Houston, Galveston, and Austin showed an increase in chroma of more than twice this least perceptible step. Chroma differences after 2 years' storage at New Bedford, New York, and El Paso came within this least perceptible step. At the other locations the variation was between 1 and 2 least perceptible steps. Therefore, only in the case of Houston, Galveston, and Austin was the color change after 2 years' storage noticeable. In nearly all cases, the chroma continued to increase during the following 3 years, but the increase in chroma in samples held in Washington for the 3 years following field storage was in all cases small, in most cases not more than the least perceptible difference step defined above.

Cottons stored in the field for 5 years showed an increase in color of less than twice this least perceptible difference at New Bedford (1), Washington (3), El Paso (13), and San Pedro (15), and those cottons can therefore be said to have shown little perceptible change. An increase of more than three times this difference was shown by cottons stored for 5 years at Charleston (4), Memphis (6), Mobile (7), New Orleans (8), Austin (9), Dallas (10), a change that is entirely noticeable; and more than four times this difference at Galveston (11) and Houston (12), a very real color change, noticeable to anyone who might look at the cotton.

The direction and relative amount of change shown in the chroma plot of figure 4 is well substantiated by the data for visual comparisons shown in figure 5. The order of difference for Mobile (7) and New Orleans (8) seems to be the only real reversal. The average data for visual comparison indicate that cottons stored in New Orleans (8) changed as much as those stored in Galveston (11) and Houston (12), but the color readings, although they show a definite increase for cottons stored at New Orleans, do not show quite this amount.

It therefore becomes evident, from a study of figures 1 and 2 as well as 3 and 4, that there is a general increase in degree of yellowness of white or light spotted cottons during storage, and that this increase varies more in relation to storage point than it does in relation to variety. Although the increase in color is more pronounced for Acala than for the other varieties of cottons studied, there was increase for all varieties at several storage locations, this increase being much more pronounced for some storage points than for others. The storage locations in which this color change is greatest have weather that is often hot and humid. It seems reasonable to suppose that high humidity combined with high temperature may be the cause, or may be associated with the cause, for this increase in color. Evidently the cause is not high temperature alone, nor high humidity alone, for El Paso and Phoenix have high temperatures with low humidity, while New Bedford has high humidity with more moderate temperatures. Average maximum and minimum temperature and relative humidity data taken at noon for the period of storage April 1936 to April 1941 by the United States Weather Bureau, are included in table 2 in order to give some indication of weather at those points. The humidity data shown are for noon, which may not always tell the whole story, as in the case of Houston and Galveston. If the data for these two storage points had been for 8:00 a.m., they would show Houston with a higher average humidity than Galveston. Evidently these figures are not entirely revealing — but they give some indication of relative weather conditions out-of-doors. Conditions within a warehouse may differ markedly from those recorded by the weather bureau.

The relative change in number of spots in the cottons stored at various locations is shown in figure 6. As in figure 3, a parallel chart for the varieties studied, figure 6 shows a great decrease in number of spots after 2 years' storage, and again there generally were more spots after 5 years' storage than after 2, though even then not nearly as many as there were originally. Although there seems to be a slight relation between decrease in number of spots and the location of storage, it is not nearly so marked as the relation between the decrease in number of spots and the varieties studied. It does look as if cottons stored in Phoenix (14) lost more spots and held that loss more consistently than did cottons stored at any other location, but there is no trend definite enough to make sure — even for Phoenix — that the results of another test would show the same order of difference.

Individual Measurements

In order that the reader may judge for himself just how much variation is included in average results, color data for individual samples are plotted in figures 7-11.

The distribution of color of individual samples segregated by 1st and 2nd pickings of varieties studied, with the code number for their location indicated for each group of data, is shown in figure 7. The data are plotted on small two-dimensional color charts, brilliance in a vertical direction, chroma in a horizontal direction. On such plots the color relation of cottons can best be judged. If different storage locations affect color differently, and if that effect is generally the same for all cottons stored at a single point, samples will appear in relatively the same position in each of the small charts of figure 7. There is considerable scatter to each set of data, and one might therefore study each one by drawing imaginary vertical and horizontal lines through the center of each group of dots so that each group is divided into reference quarters.

Varieties

A

1

2

B

1

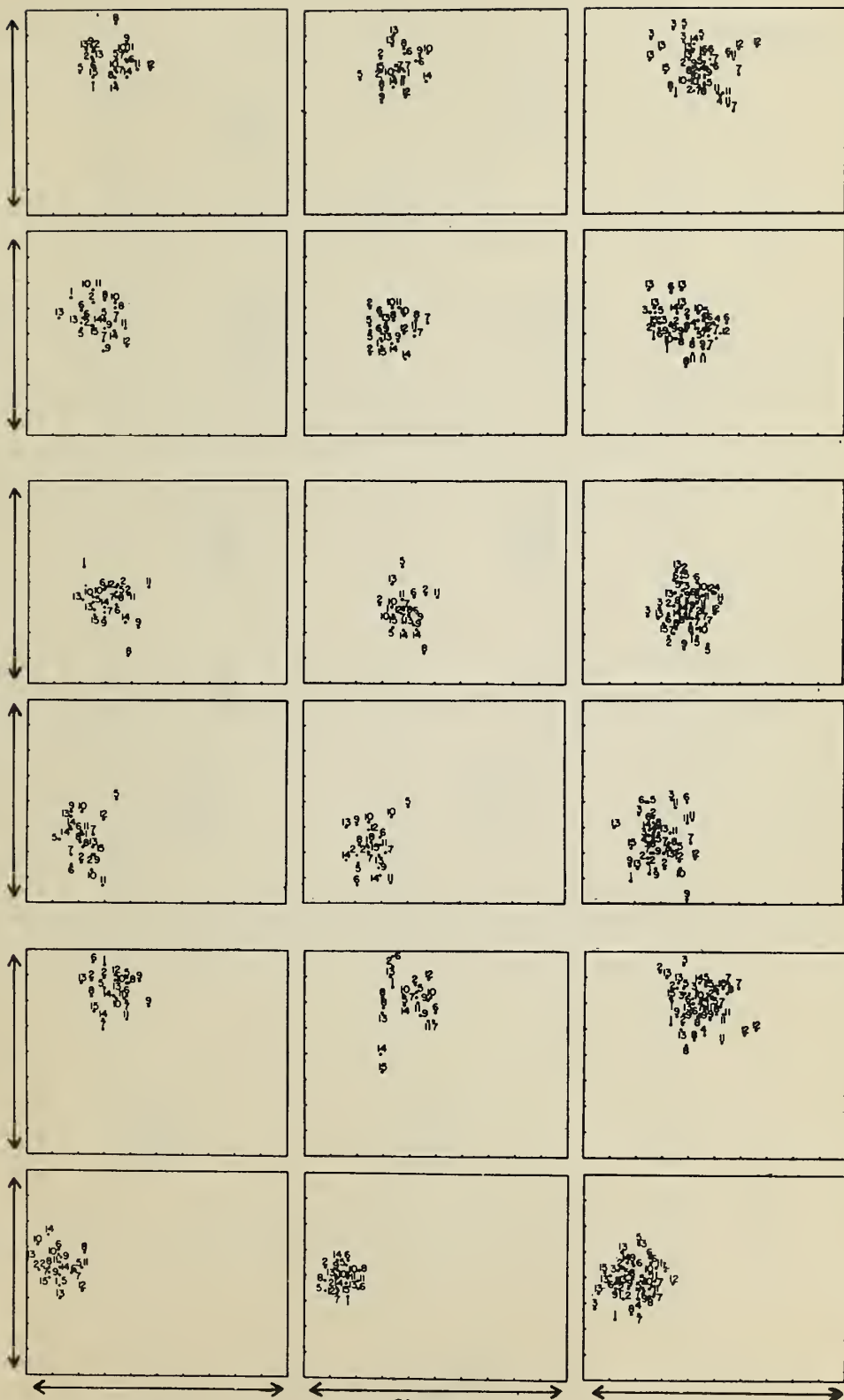
2

Brilliance

C

1

2



2 years field storage

2 years field storage,
3 years in Washington

5 years field storage

Figure 7. — Color measurements after storage. Distribution by varieties of individual measurements of samples stored at each storage point. See table 2 for code numbers. Each small plot shows distribution by brilliance (vertical) and chroma (horizontal).

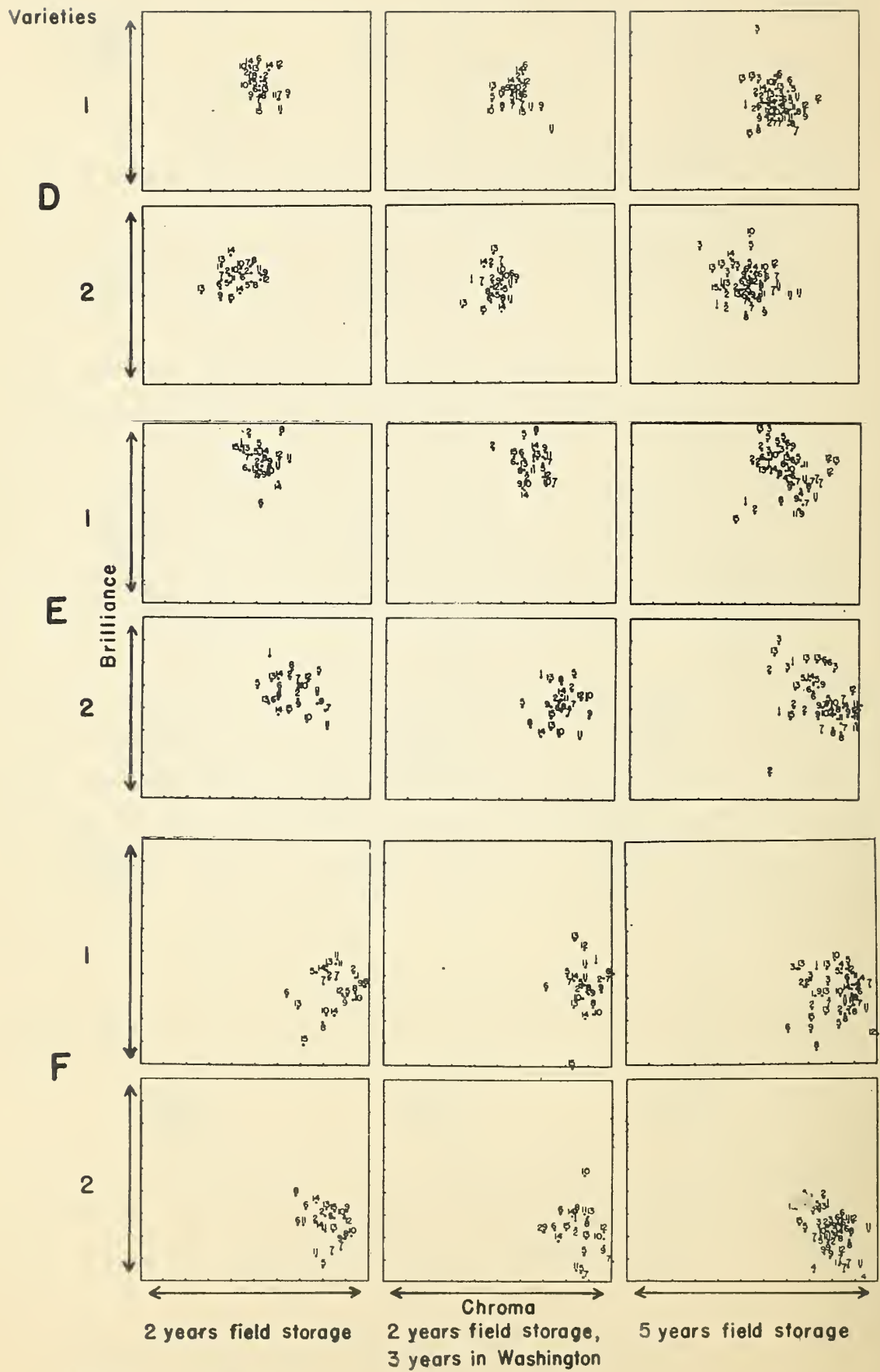


Figure 7. Cont'd.

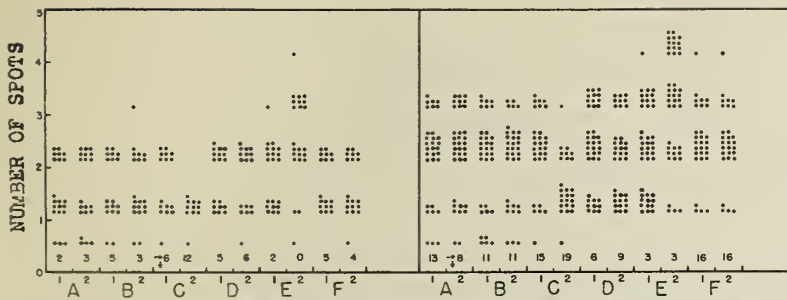


Figure 8. — Increase in yellowness after storage, by visual comparison to whitest box. Distribution of individual measurements, by varieties. The first group represents 23 samples of each variety stored 2 years in the field, then 3 years in Washington; the second group represents 45 samples of each variety stored 5 years in the field.

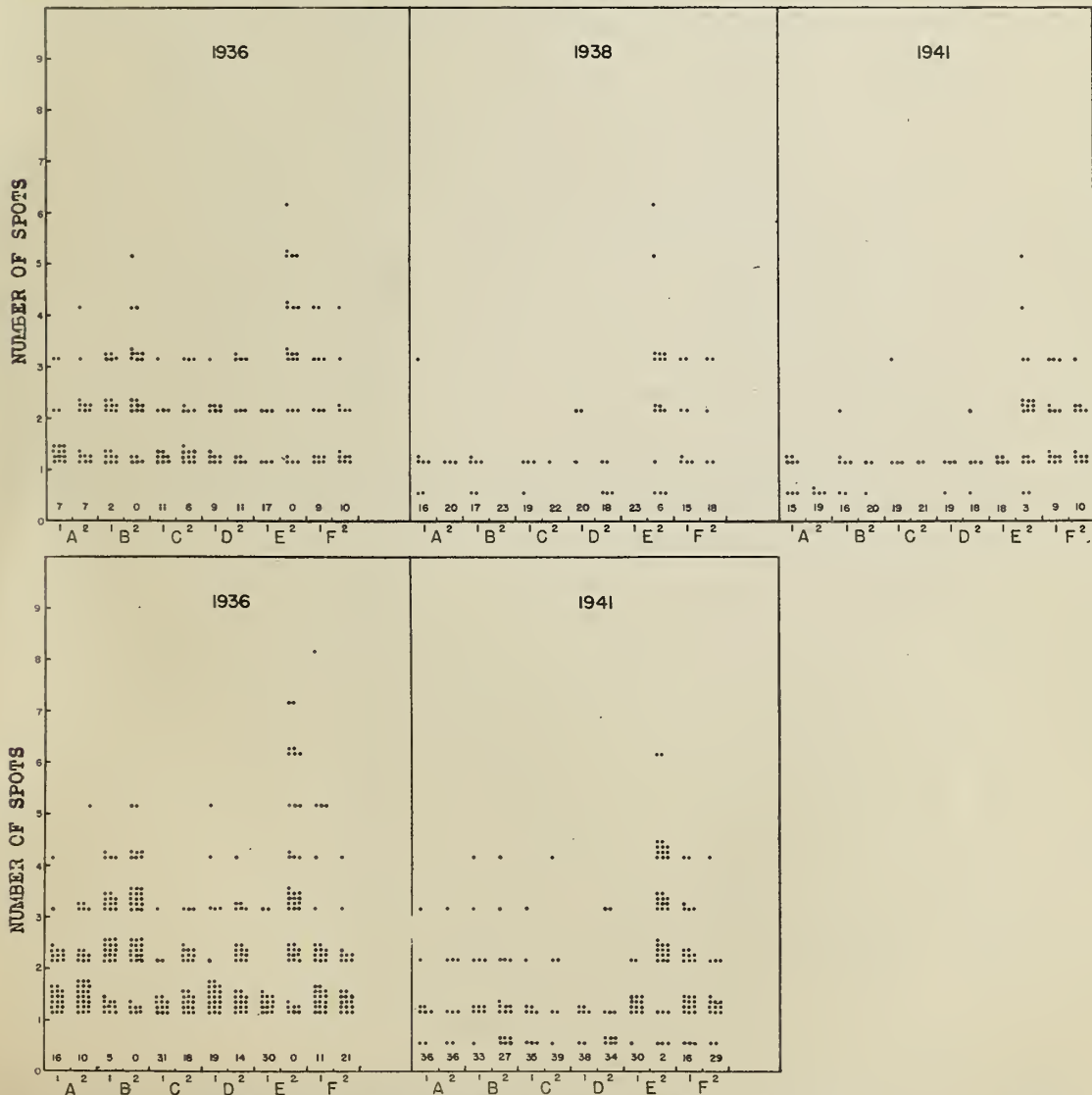


Figure 9. — Number of spots before and after storage. Distribution of individual measurements, by varieties. The upper group (1936, 1938, 1941) represents 23 samples of each variety stored in the field 2 years, then in Washington 3 years; the lower group (1936, 1941) represents 45 samples stored in the field 5 years.

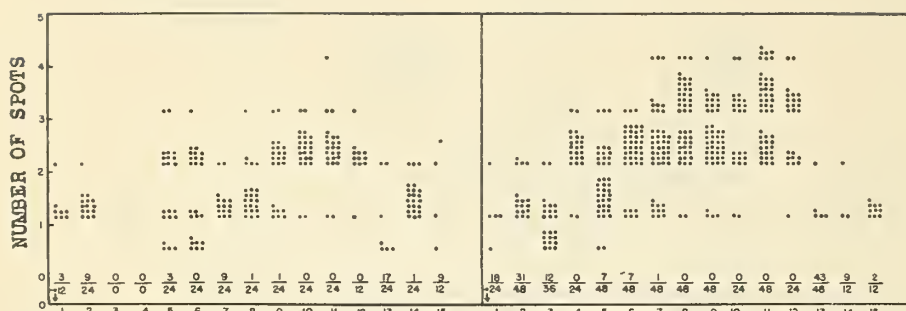


Figure 10. — Increase in yellowness after storage, by visual comparison to whitest box. Distribution of individual measurements, at 15 locations. The first group represents cottons stored 2 years in the field, then 3 years in Washington; the second group was stored 5 years in the field.

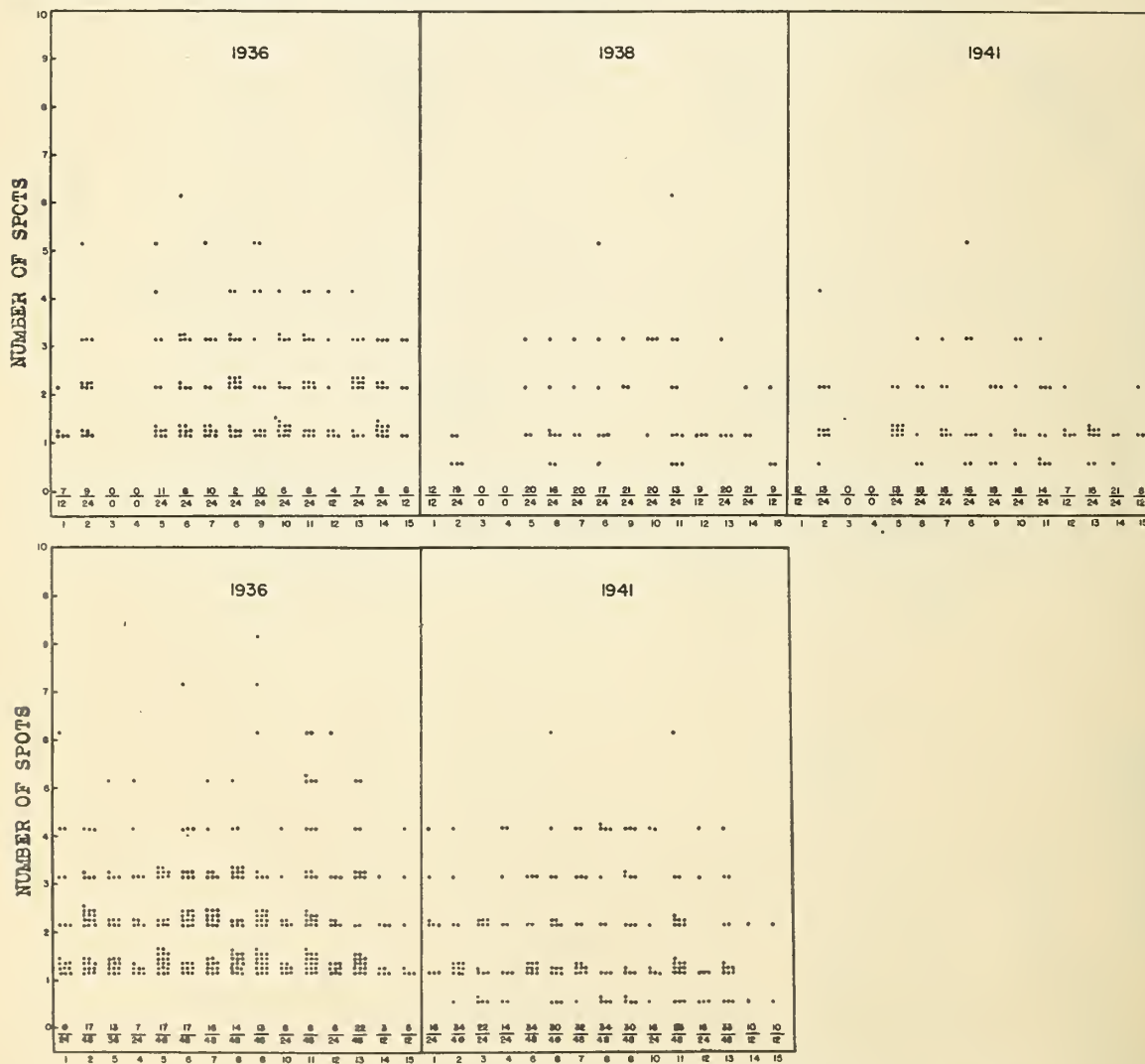


Figure 11. — Number of spots before and after storage. Distribution of individual measurements, at 15 locations. The upper group (1936, 1938, 1941) represents cottons stored in the field 2 years, then in Washington 3 years; the lower group (1936, 1941) represents cottons stored in the field 5 years.

If there is a pronounced effect of storage on color change, then the numbers representing different locations will tend to fall in the same relative position on each chart. Extremes are El Paso (13), which is generally in the lower or upper left quarter of the chart, New Bedford (1), generally in the lower or upper left quarter, Houston (12), generally in the right upper or lower quarter. Because chroma, rather than brilliance, is the color factor most affected by storage, the samples will fall more definitely to the right or left of the imaginary vertical line than they will above or below the imaginary horizontal line. Although there is much scatter, it is nevertheless not difficult to see how well the average results in figures 1 and 4 represent the data.

The distribution of individual judgments of increase in yellowness is shown in figure 8 by varieties and in figure 10 by locations. Since there were 23 boxes returned after 2 years' storage in the field, and 45 boxes after 5 years' storage in the field, in figure 8 the number of individual dots in each sub-group for the cottons stored in the field 2 years (afterwards stored in Washington 3 years) is 23; for the cottons stored in the field 5 years, the number of dots is 45. In figure 10 the number of dots in each sub-group is 12 times the number of boxes returned after storage at a given location (12 samples to each box). The dots representing individual samples stored 2 years in the field total 12 or 24; dots representing samples stored 5 years in the field total 24 to 48 (table 2 explains why the same number of boxes were not returned from each location). For convenient reference, the total number of samples returned at each point is placed on figures 10 and 11. The distribution of individual observations shown in figures 8 and 10 should be compared with the average results in figures 2 and 5. It can be seen that the average data represent the individual data very well, and that color change is more definitely associated with location of storage than with the variety stored.

The distribution of the number of spots in individual samples is shown in figure 9 by varieties, and in figure 11 by storage location. Some cottons had less spots than others, as may be seen by the relative distribution for each variety and picking. This difference is not shown in the averages in figure 3 since for ease of comparison those averages, as well as those in figure 6, are shown as a percentage of change in number of spots. In figures 9 and 11, the actual number, as well as relative change, can be seen by inspecting the chart. Since there are 23 samples in the group stored 2 years in the field and 45 samples in the group stored 5 years in the field, the number of dots in each sub-group of figure 9 will total 23 and 45, as they did for figure 8; the dots in figure 11 will total the same as they did for figure 10. Even a casual inspection of the charts shows the results to be as presented by the average figures; that is, the degree of change in number and intensity of spots during storage seems determined more by the variety stored than by the storage location.

SUMMARY

Samples representing six well known commercial varieties of cottons, 1st and 2nd pickings of each, graded white or light spotted, were obtained in quantities large enough to prepare replicate boxes. The samples were put up like the grade standards with the same position in each box containing similar cottons. These boxes, in groups of three, were distributed to 15 locations, from New Bedford, Mass., to San Pedro, Calif, for office and warehouse storage. After 2 years' storage one box of each group was recalled from each storage place; the remaining two boxes were recalled after 5 years. On recall, each sample was measured for color, and all spots were counted and compared with marked photographs of the original samples. At the end of the test, visual comparisons of all samples were made against the box that had changed the least.

Results of the test are shown in a series of charts. The outstanding difference shown by color measurement of the samples is the increase in chroma (a measure of the general increase in depth of yellowness) for all varieties of cottons that were stored. Except for the Acala cotton included in the test, this increase was not so great for the first 2 years of storage, but it was quite significant for all varieties after 5 years. The direction of change was the same in all cases, but on the whole the 2nd picking, except for Acala, did not change quite as much as the 1st picking. Location of storage had a great deal to do with the degree of chroma change, cottons stored 5 years at Houston, Galveston, and Mobile show much more change than those stored at New Bedford, New York, Washington, El Paso, and San Pedro. There was a noticeable change even for 2 years' storage at Houston, Galveston, and Austin. Data for visual comparison substantiated the results shown by chroma measurements.

The change in number and intensity of spots was considered apart from the change in general background color. All the cottons studied lost a high percentage of their spots within 2 years. They seemed to gain a few during the next 3 years, but not enough to equal or even approach the number that each had at the beginning of the test. In direct contrast to the results for change in background color, the change with respect to spots during storage seems to depend more upon the kind or variety of cotton stored than upon the location of storage.